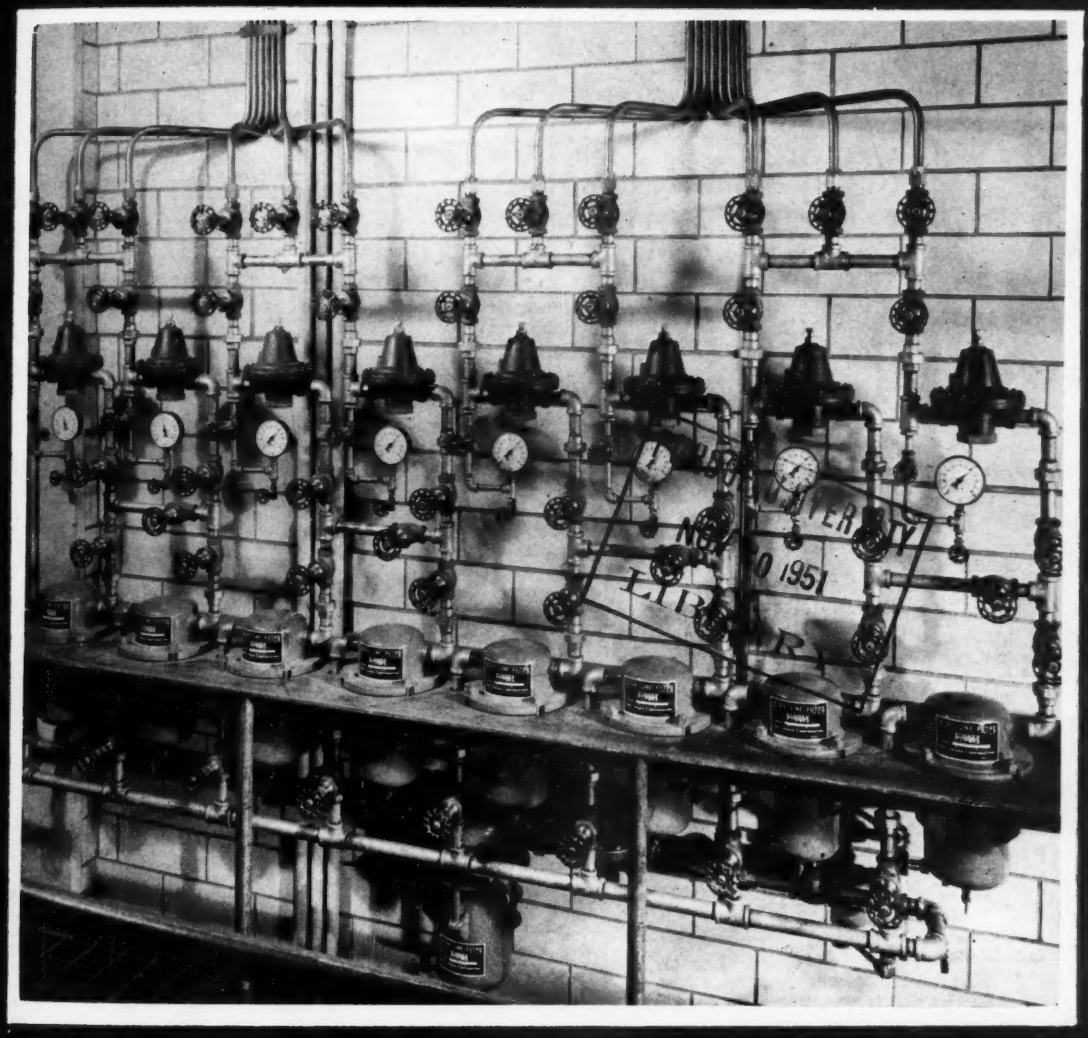
Instruments

THE MAGAZINE of MEASUREMENT and CONTROL

Vol. 24 | NOVEMBER 1951 | No. 11

INCLUDING THE *Journal of the Instrument Society of America*

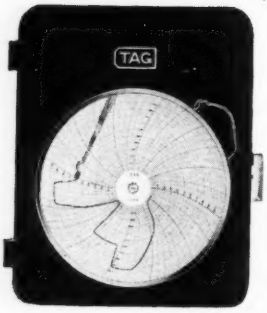
AND THE *Journal of the Southern California Meter Association*



Filter bank for the air-operated instruments on one of the main boilers at the new Russell Station, Rochester (N.Y.) Gas and Electric Corp. Story on page 1345. ***(Courtesy Dollinger Corp.)***

1,000°F.

Where molecules DANCE or DIE...



TAGLIABUE RECORDERS *Chart Changing Temperatures*

From the mad molecular dance at a thousand degrees to the killing cold of three hundred below, TAGliabue Recorders faithfully chart changing temperatures for future reference. Whether your requirements are for a sensitive instrument spanning but a few degrees . . . for a model built for one temperature extreme or the other . . . or for a conventional instrument that's adaptable to myriad industrial applications—you will find a TAG Temperature Recorder that meets your every need.

And in all TAG Recorders you can count on the same simple, sound design . . . the same sturdy construction . . . that have long kept TAGliabue leaders in temperature instrumentation.

Feel free to call on your TAG Representative for assistance in applying these modern instruments to your processes.

0°F.

−300°F.

TAG **TAGLIABUE INSTRUMENTS DIVISION**

Weston Electrical Instrument Corporation

614 Frelinghuysen Avenue, Newark 5, New Jersey

Dielectric Moisture Meter Checks Various Materials

Moisture content of finely powdered, relatively dry, or coarse and oily materials is determined in less than two minutes with the versatile Model 8007 Dielectric Moisture Meter developed by TAGliabue Instruments Div., Dept. 67, Weston Electrical Instrument Corp., Newark 5, N. J. Operating over an extremely wide range, this meter functions without damaging the sample.

To use, a weighed sample is placed in a cell inserted in the instrument. The meter shows the material's capacitance, which simple tables convert into percent moisture. Chemicals, dehydrated foods, soaps, flours, seeds, plastic molding powders, iron ore, coal, cheese, coffee, corn, grain, dried leaf, flue dust, starch, yeast and cottonseed typify materials tested.

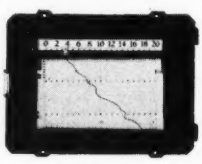
"TAG" Glass Thermometers Provide Lasting Precision

Accurate general purpose and laboratory thermometers are supplied by TAGliabue Instruments Div., Dept. 67, Weston Electrical Instrument Corp., Newark 5, N. J. Available armored or unarmored, these individually etched stem thermometers indicate temperatures as low as —150° or as high as 950°F. in the standard grade, and values as low as —30°F. or as high as 750°F. in the extreme precision grade. Limited range thermometers graduated to 1/100°C., for calorimeter use, are also standard.

In addition to individual instruments, matched sets of A.S.T.M. Testing Thermometers, with overlapping ranges spanning temperatures from —36°F. to 760°F., or —38 to 405°C., are available in convenient simulated leather cases.

TAG-Weston Light Recorder Charts Illumination Changes

Fluctuations in illumination are accurately charted by the TAG-Weston photoelectric light recorder introduced by TAGliabue Instruments Div., Dept. 67, Weston Electrical Instrument Corp., Newark 5, N. J. Developed to chart the fast-changing light output of railway fusees, this new instrument also lends itself to many applications where wide variations in light intensity must be recorded faster than by hand.



The "Photronic" photoelectric cell sensing element can be placed wherever convenient. The wall-mounted CELECTRAY recorder, of proved TAGliabue design, follows rapid changes without overshooting or hunting. Full scale values of 20, 40 or 80 foot-candles are selected by a single switch.

More NEW GR UNIT INSTRUMENTS

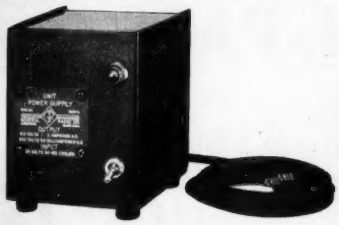
Simple • Compact • Rugged

Interchangeable Laboratory-Type Equipment at Moderate Prices

SOME months ago General Radio announced the availability of its 'unit' line of inexpensive instruments designed for general laboratory use. Each unit is complete in itself, with straightforward circuit, good accuracy, and with plug-in power supply which automatically furnishes proper filament and plate voltages.

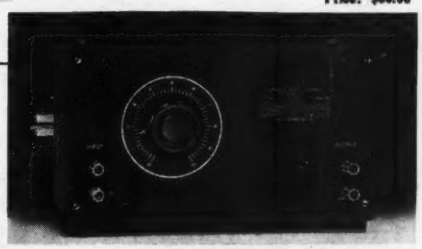
These units are electrically and mechanically interconnectable and can be combined to provide a number of essential power sources for both audio- and radio-frequency measurements. Units can be assembled to make inexpensive standard-signal generators, test oscillators, heterodyne detectors, voltage calibrators, power sources for slotted line measurements, null detectors, etc.

This line of unit instruments is inexpensive, flexible and versatile and comprises basic measuring equipment either for general laboratory use or for specialized measurements. Several new units are described in the following:

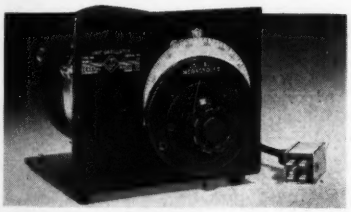


Type 1203-A Unit Power Supply This new unit supplies voltages of 6.3 for cathode heaters at 3 amperes maximum, and 50 ma at 300 volts dc, maximum. The no-load voltage is 410. Hum level is 250 mv at 300 volts and 50 ma d-c output. Connections to associated unit equipment are made through a standard multipoint connector mounted in the ends of the unit. A mating multipoint connector for connecting the supply to other equipment is furnished. **Price: $47.50**

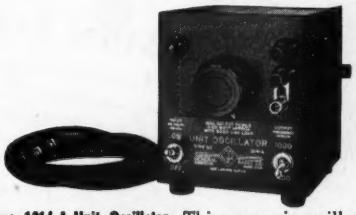
Type 1204-B Variable Power Supply This is a general-purpose variable-output power unit. It is equipped both with multipoint connectors for plugging into other unit instruments and with binding posts for connecting to other equipment. It furnishes cathode supply of 6.3 volts ac at 3 amperes maximum, and d-c plate supply continuously adjustable from zero to 300 volts with a maximum load of 100 ma. A panel meter shows the d-c output voltage and current. The hum level is 250 mv at 300 v, 100 ma d-c load. A mating multipoint connector is supplied. **Price: $85.00**



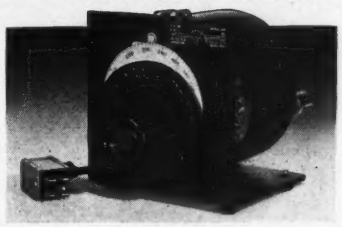
Type 1206-A Unit Amplifier This unit amplifier uses two triode, RC-coupled, voltage-amplifier stages and an impedance-coupled output stage. It furnishes a maximum voltage gain of 45 db, continuously adjustable from zero with a maximum output of 3 watts into 7500 ohms, with distortion of less than 2% at frequencies above 100 cycles. The frequency response is essentially flat from 100 cycles to 100 kc. **Price: $85.00**



Type 1209-A U-H-F Unit Oscillator This *new* unit oscillator has a continuous tuning range of 250 to 920 Mc. It uses a Butterfly Circuit with no moving contacts. Output coupling is a short coaxial line with a coupling loop and a G-R Type 874 Coaxial Connector. Coupling can be varied over a wide range. The calibration accuracy is ± 1%. The output power is 200 mw into 50 ohms at any frequency. Amplitude modulation of 30% can be provided from an external source of 40 volts. Input impedance is about 8000 ohms. **Price: $235.00**



Type 1214-A Unit Oscillator This new unit oscillator supplies frequencies of 400 and 1000 cycles, accurate to ± 2%. It is a convenient modulator for the Types 1208-A and 1209-A Unit Oscillators, and is widely used as a power source for bridge measurements. This oscillator contains its own power supply, unlike other G-R unit instruments. Maximum output power is over 200 mw. Output impedance is about 8000 ohms at maximum output. Open-circuit output voltage is about 80 volts. A toggle switch selects either the 400-cycle or 1000-cycle output. **Price: $60.00**



Type 1208-A V-H-F Oscillator This unit oscillator is similar to the Type 1209-A in construction and operation. The tuning circuit employs a sliding contact which makes possible a wider frequency range of 65 to 500 Mc. The frequency calibration is accurate to ± 2%. Into 50 ohms the output power is 100 mw at any frequency and 500 mw in the center of the range. **Price: $190.00**

GENERAL RADIO Company

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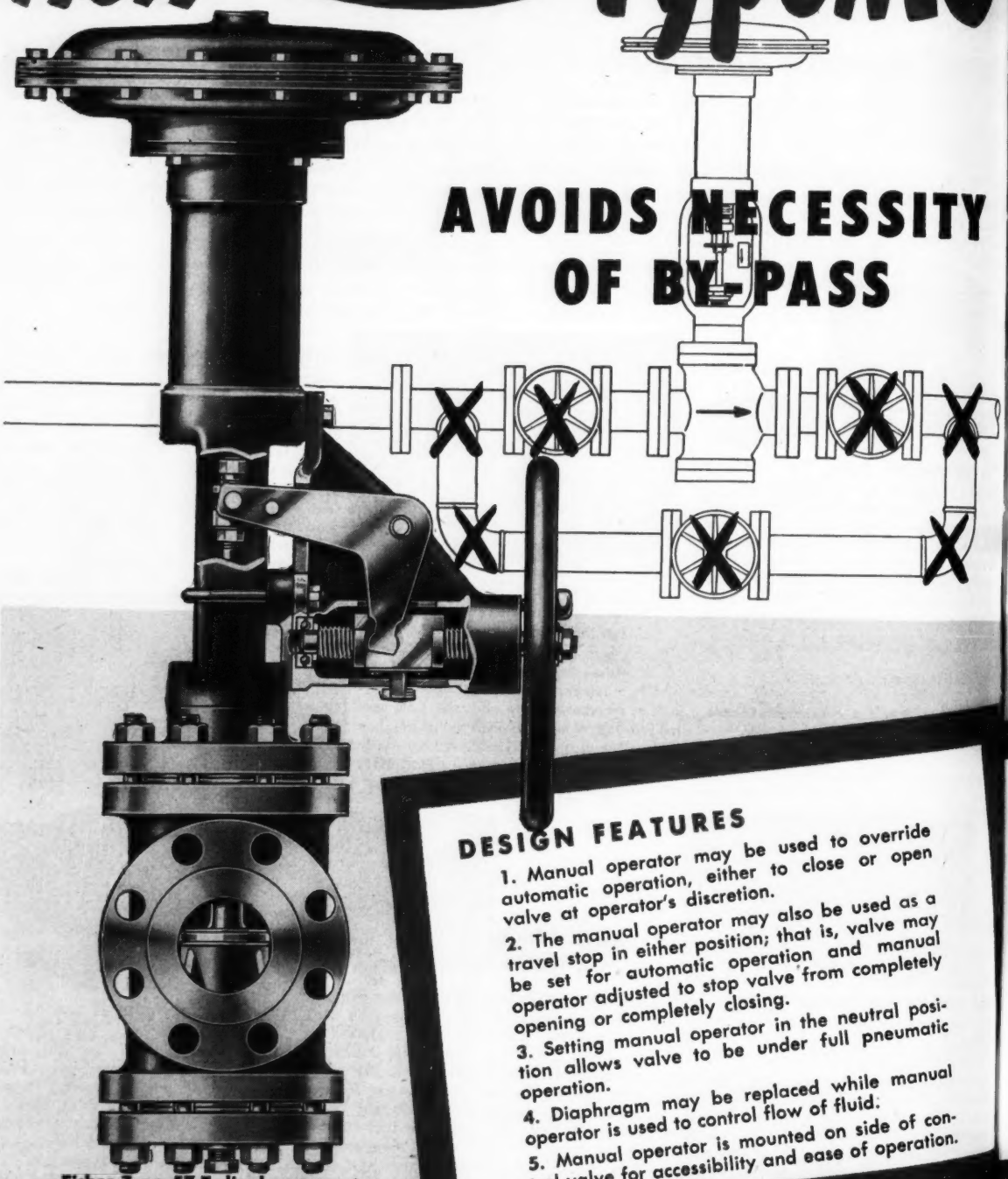
Other G-R Unit Instruments are under development and will be available in the future. Watch for them.

New FISHER Type MO

AVOIDS NECESSITY OF BY-PASS



Fisher Type 57-T diaphragm motor valve with side mounted Type MO handwheel operator in section.

DESIGN FEATURES

1. Manual operator may be used to override automatic operation, either to close or open valve at operator's discretion.
2. The manual operator may also be used as a travel stop in either position; that is, valve may be set for automatic operation and manual operator adjusted to stop valve from completely opening or completely closing.
3. Setting manual operator in the neutral position allows valve to be under full pneumatic operation.
4. Diaphragm may be replaced while manual operator is used to control flow of fluid.
5. Manual operator is mounted on side of control valve for accessibility and ease of operation.

FISHER

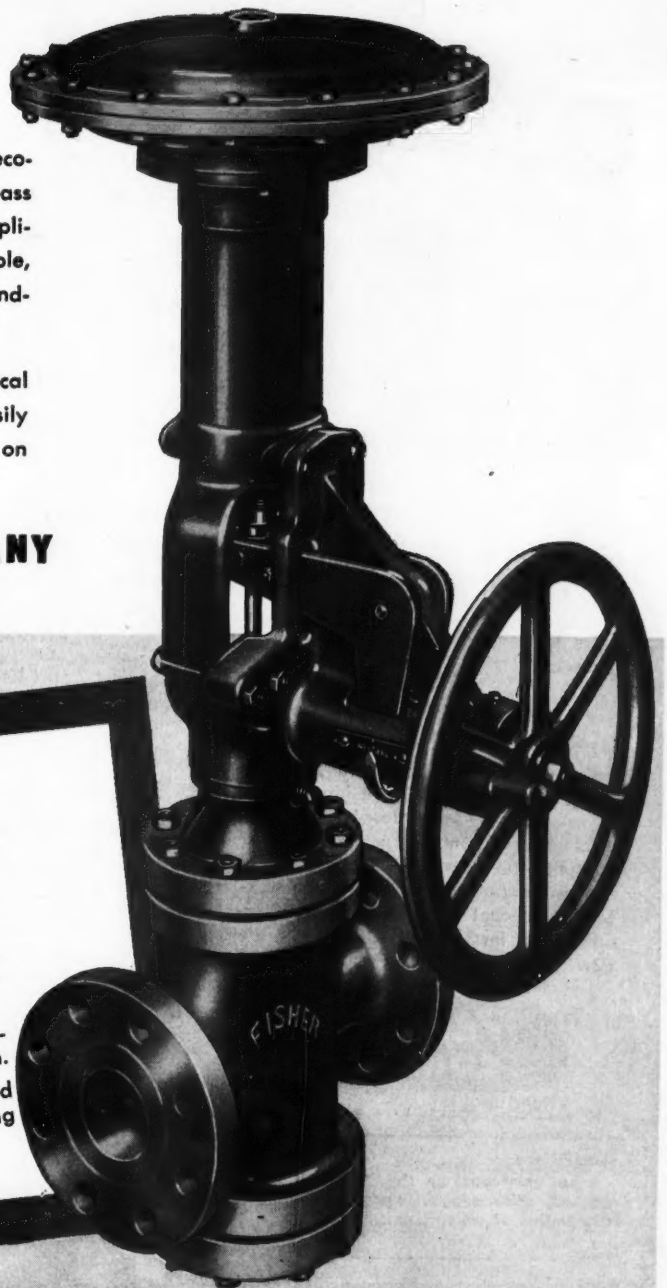
WORLD LEADER IN THE MANUFACTURE OF PRESSURE

Manual Operator

In some applications it may be desirable or economical to place responsibility of the by-pass function upon the control valve. For these applications, select the **Fisher Type MO.** It is a simple, rugged, economical, continuous connected handwheel operator that will handle this problem.

Construction places the handwheel in a vertical plane, making it more accessible and more easily handled than handwheel commonly mounted on top of diaphragm case.

FISHER GOVERNOR COMPANY
MARSHALLTOWN, IOWA



CONSTRUCTION FEATURES

1. Handwheel fitted with spring loaded ball and socket recess to retain wheel in position when not in operation.
2. May be mounted on control valves in field that have tapped bosses on yoke. Requires only new diaphragm rod, adjusting screw and stem connector.
3. Grease packed radial and thrust bearings insure long life and easy operation.
4. Handjack operating screw constructed with pitch to give adequate operating power.

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by
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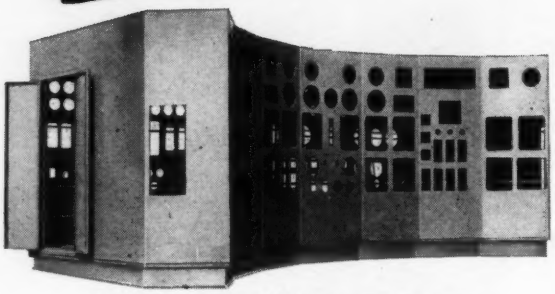

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Instruments
THE MAGAZINE OF
Measurement and Control

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Statement of Ownership, page 1346

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MODEL 81TT5 is provided with calibration steps similar to the 81TT9, except that a range of zero to 600°F copper-constantan is substituted for the 0 to 1000°C chromel-alumel range, to provide means of checking this type of indicator found on some commercial aircraft.

Only a few simple operations are required to test temperature indicators with these instruments. Connect the indicator with the clip or plug leads, turn the resistance-voltage switch as required, adjust standardizing voltmeter to a red line by means of the rheostat and turn temperature selector switch. By comparing the indicator reading with the switch setting, the scale error of the indicator is determined.

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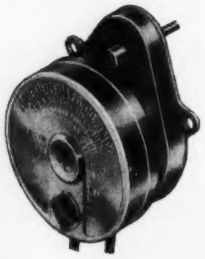

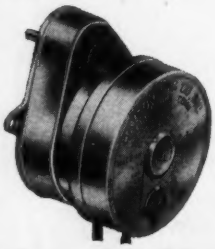

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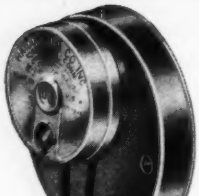

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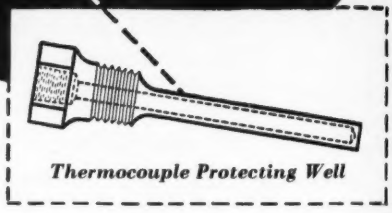

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3. *Made of practically all common metals and alloys . . . of almost any wall thickness, to withstand high temperatures and pressures.*

4. *Quick delivery . . . stocks maintained at branch offices.*

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Brown Instruments

STAINLESS STEEL BELLOWS ASSEMBLIES

When time counts—and accuracy and quality are "musts"—you can entrust your stainless steel bellows assemblies needs to us . . . *completely!*

Just turn over the job to us. You're free of production problems and worries. Our skilled personnel—ample facilities—50 years of specialized experience—all combine to produce *exactly* to your specifications. You save *plenty* —time *and* money.

You may need an assembly similar to one we have already produced. Or, you may have a design problem that parallels one we have solved for another customer. Whatever you require, we will work with you to develop assemblies specifically adapted to your requirements.

Sylphon bellows assemblies are used in many ways—where there's a design problem involving control of temperatures or pressures. They open and close valves, dampers, etc., absorb expansion, provide packless construction, have many more uses. Stainless steel or other metals. Wide range of sizes. Send for complete information. Ask for idea-packed Catalog VE-1200.

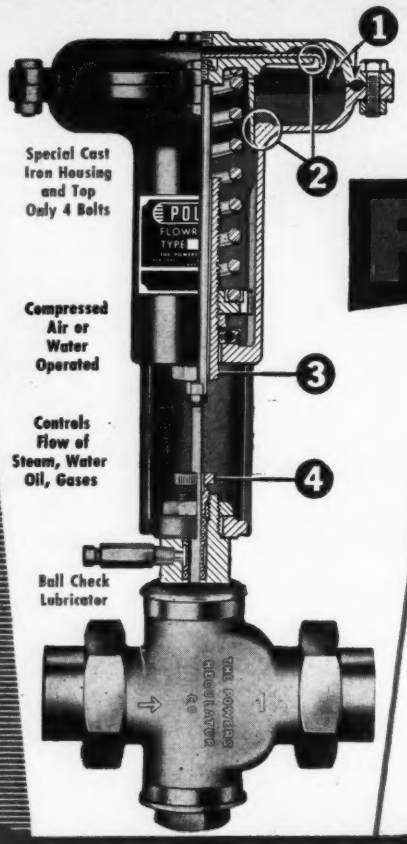
TEMPERATURE CONTROLS

FULTON SYLPHON DIVISION
Knoxville 4, Tenn.

Robertshaw-Fulton CONTROLS COMPANY

BELLOWS ASSEMBLIES • BELLOWS DEVICES

BRIDGEPORT THERMOSTAT DIVISION
Bridgeport 1, Conn.



POWERS FLOWRITE VALVE

★ **VALVE TOP**—Durable moulded neoprene diaphragm (1) has positive sealing bead which provides increased sealing action with increasing control pressure. Efficient diaphragm form insures ample and constant operating power thru full travel. Piston Plate Assembly (2) has a free floating thrust plate which absorbs side thrust. Closely guided piston plate maintains stem in accurate alignment.

★ **ADJUSTING SCREW**—Ball bearing non-rising type. Easily accessible, 180° turning radius with starting pressure adjustable from 0 to 17 psi. Has enclosed rust proofed steel spring for full travel in 5 or 10 psi. control pressure change.

★ **BONNET ASSEMBLY**—Polished stainless steel stem in preformed lubricated metallic packing insures long life and low hysteresis.

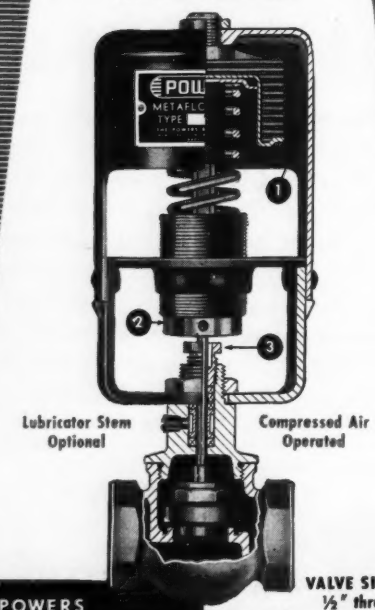
VARIETY of VALVE BODIES — Sizes ½" thru 8"—For line pressures below 250 psi. Rugged construction to withstand piping strains. Single seat or double seat, bronze and stainless steel trim. Double unions and flanged ends. Available normally open (direct acting) or normally closed (reverse acting) and 3-way type valves.

POWERS

BETTER Valve Tops

Get TOP Performance WITH THESE AND Reduce Maintenance

Packless Valves Available



POWERS METAFLOW VALVE

VALVE SIZES— ½" thru 2"

Bronze bodies, screwed ends. Rugged construction to withstand piping strains.

POWERS *Metaflow Valves* are small, sturdy, light-weight, reasonably priced, suitable for many control applications where the pressure differential does not exceed 75 lbs. per square inch.

1. HOUSING—High strength aluminum alloy. Hydraulically formed long life brass bellows provides smooth and powerful stroke.

2. ADJUSTING SCREW—Brass with rust proofed steel spring having 15 lbs. adjustment range to give proper sequence operation where required.

3. BONNET ASSEMBLY—Polished stainless steel stem in preformed lubricated metallic packing insures long life and low hysteresis.

TRIM—Composition disc with brass integral seat and self-aligning disc holder. Available normally open (direct acting) or normally closed (reverse acting), and 3-way.

METAFLOW NO-PAK VALVES prevent leakage of inflammable or harmful liquids or gases and provide vacuum protection. Are suitable for use with Freon, oil, gasoline, non-corrosive gases, hot or cold water and low pressure steam.

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OFFICES IN OVER 50 CITIES • See Your Phone Book

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OVER 58 YEARS OF PNEUMATIC TEMPERATURE CONTROL

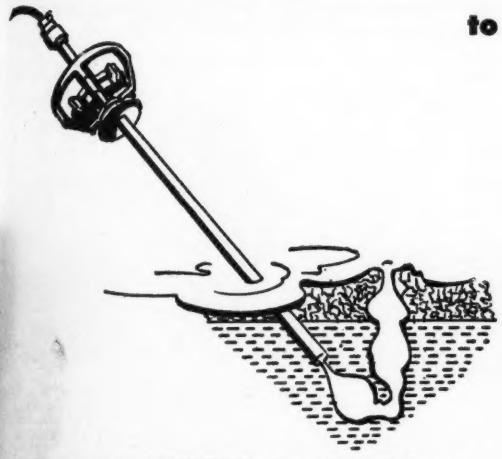
(FM3)

For more profitable heats

choose

IMMERSION RAYOTUBE or IMMERSION THERMOCOUPLE

to measure temperatures in the steel bath



THE IMMERSION RAYOTUBE is plunged beneath the surface of the bath . . . sights on an air pocket blown in the steel . . . reports temperature to a Speedomax Recorder.

THE IMMERSION THERMOCOUPLE is immersed until couple reaches bath temperature . . . a process guided by signal lights and charted on a Speedomax Recorder.

Open hearth and electric furnace shops can now choose between *two* tested L&N methods for measuring steel temperatures during the melt. Either the Immersion Rayotube or Immersion Thermocouple is plunged momentarily beneath the surface to measure the interior temperature of the bath, while a dependable Speedomax Recorder displays the information where all concerned can use it.

Either method helps improve ingot production by warning if the steel is too hot or too cold for normal pouring. Authorities* have found that some ingots from as many as 44% of overheated melts will stick to the molds, resulting in loss of production time, while as many as 52% of underheated melts will lose yield through formation of skulls in the ladle. *Both of these losses have been sharply cut in every plant where temperature is properly measured while the melt is finished off for tapping.*

Investigate the choice of immersion methods L&N offers to meet plant requirements. *In general,* Rayotubes are employed in heavy-duty shops where several readings may be taken every hour, while thermocouples—although sometimes preferred for such service—find wider application to small or special furnaces. However, a number of factors determine the final choice. Let our experienced engineers analyze your measurement problems and help your staff select the proper equipment.

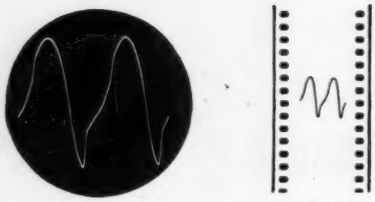
Contact our nearest office, or write us at 4955 Stenton Avenue, Philadelphia 44, Pa.

* Clark and Feigenbaum of J&L, in AIMME Technical Paper 2031.

LEEDS NORTHRUP

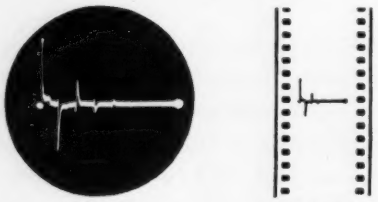
Jrl Ad N-33-640(2)

How much can you expect an oscilloscope camera to do?



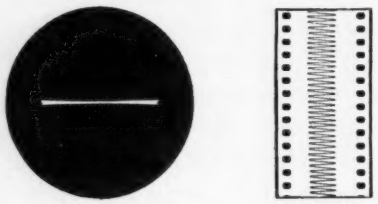
Scope Image — Film Recording

1. Single-frame photography of stationary patterns using a continuously running sweep.



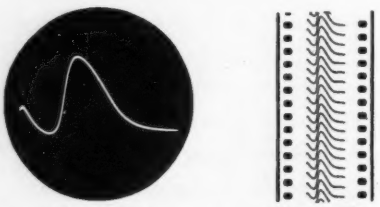
Scope Image — Film Recording

2. Single-frame photography of single transients using a single sweep.



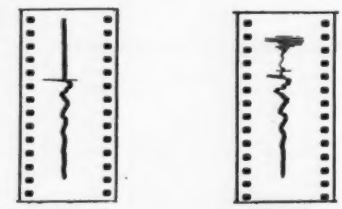
Scope Image — Film Recording

3. Continuous-motion photography employing film motion as a time base.



Scope Image — Film Recording

4. Continuous-motion photography employing oscilloscope sweep as a time base.



FILM MOTION TIME BASE — FILM MOTION & SCOPE SWEEP

5. Continuous-motion photography employing combination of film motion and oscilloscope sweep as a time base.

It's only reasonable that you should expect the oscilloscope camera you buy to record what you see on an oscilloscope screen during any period. But can it be expected to do any more? We think so.

For example, did you know that the *Fairchild Oscillo-Record Camera*—our idea of the most versatile 35-millimeter oscilloscope camera now available—can GREATLY EXTEND THE USEFULNESS OF YOUR OSCILLOSCOPE?

As you know, many non-recurring phenomena occur too rapidly to permit adequate visual study. Others occur so slowly that continuity is lost. Sometimes you have combinations of very slow-speed phenomena and occasional high-speed transients. In any one of these cases, the Fairchild Oscillo-Record Camera will take over where your eye and the oscilloscope leave off.

This extremely versatile instrument is now being used daily by many hundreds of engineers in widely divergent fields. For an idea of what it can do for you, study the five scope images and recordings illustrated at left. Each solves a particular problem.

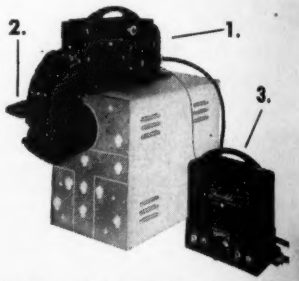
Oscillo-Record users especially like its:

CONTINUOUSLY VARIABLE SPEED CONTROL—1 in./min. to 3600 in./min.

TOP OF SCOPE MOUNTING that leaves controls easily accessible.

PROVISION FOR 3 LENGTHS OF FILM—100, 400, or 1000 feet.

For more data write *Fairchild Camera Instrument Corp., 88-06 Van Wyck Blvd., Jamaica 1, N. Y. Dept. 120-16F.*

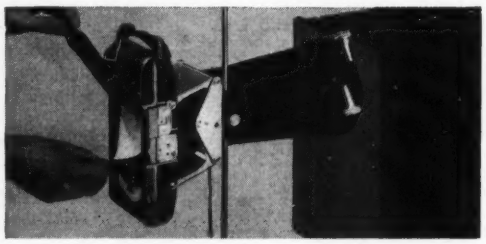


FAIRCHILD OSCILLO-RECORD CAMERA—1. camera, 2. periscope, 3. electronic control unit. *Available accessories* include external 400 and 1000 foot magazines, magazine adaptor and motor, universal mount for camera and periscope, binocular split-beam viewer.

VALUABLE RECORDS FOR IMMEDIATE EVALUATION

The Fairchild-Polaroid® Oscilloscope Camera produces a photographic print in a minute

Valuable but inexpensive oscillograms for immediate evaluation; automatic one-minute processing without a darkroom; a set up time of two minutes or less—they're just three of the many advantages that are yours when you use the Fairchild-Polaroid Oscilloscope Camera. Wherever individual exposures meet your recording requirements—where you'd like to have permanent records of the traces you're now sketching or carrying in your memory, this is the camera that can bring new speed, ease and economy to your job. Prints are 3¼x4¼ and each records two traces exactly one-half life size. Write today for details.



A minute after you've pulled the tab a finished print is ready for evaluation

FAIRCHILD
OSCILLOSCOPE RECORDING CAMERAS

WHEREVER ACCURACY COUNTS...

You Can Count on...

CLIMAX
BS&B
CONTROLS

SUN OIL COMPANY'S big, modern Natural Gas plant at Delmita, Starr Co., Texas —where 99% of the automatic valves and controls are Climax.

For control of pressures, temperatures, levels and flow—industries look to Climax Controls for the exacting reliability they require.

Accuracy is initiated at the BS&B Climax Controls division, where every control and valve must undergo rigid tests before delivery; and where engineers, metallurgists and laboratory technicians are constantly exploring and developing new materials, new methods, new and improved products, and new ideas.

In the Chemical, Petro-Chemical, Oil and Gas Industries, especially, the name "Climax" has become synonymous with efficiency and trouble-free performance.

At the International Chemical Exposition, *November 26 through December 1, you will have an opportunity to see these latest developments in Climax Controls at booths 496 and 497. We invite your visit. If you cannot attend, why not write for the latest issue of the Climax Controls catalog, on your company letterhead.*

BS&B

BLACK, SIVALLS & BRYSON, INC.

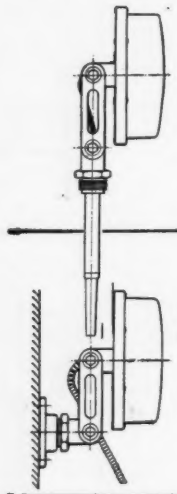
Climax Controls Division, Dept. 50-V

7500 East 12th Street Kansas City 3, Missouri

PALMER

mercury actuated Dial Thermometers

now in three types to suit any requirements

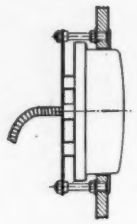


1 Rigid Stem Dial Thermometer

Rigid stem tapered bulb, interchangeable with standard industrial thermometer separable socket.

2 Wall Mounted Dial Thermometer

Wall mounted dial thermometer with flexible connecting armor. Case adjustable to easy reading position.



3 Flush Mounted Dial Thermometer

Flush mounted style for panel mounting with flexible connecting armor.

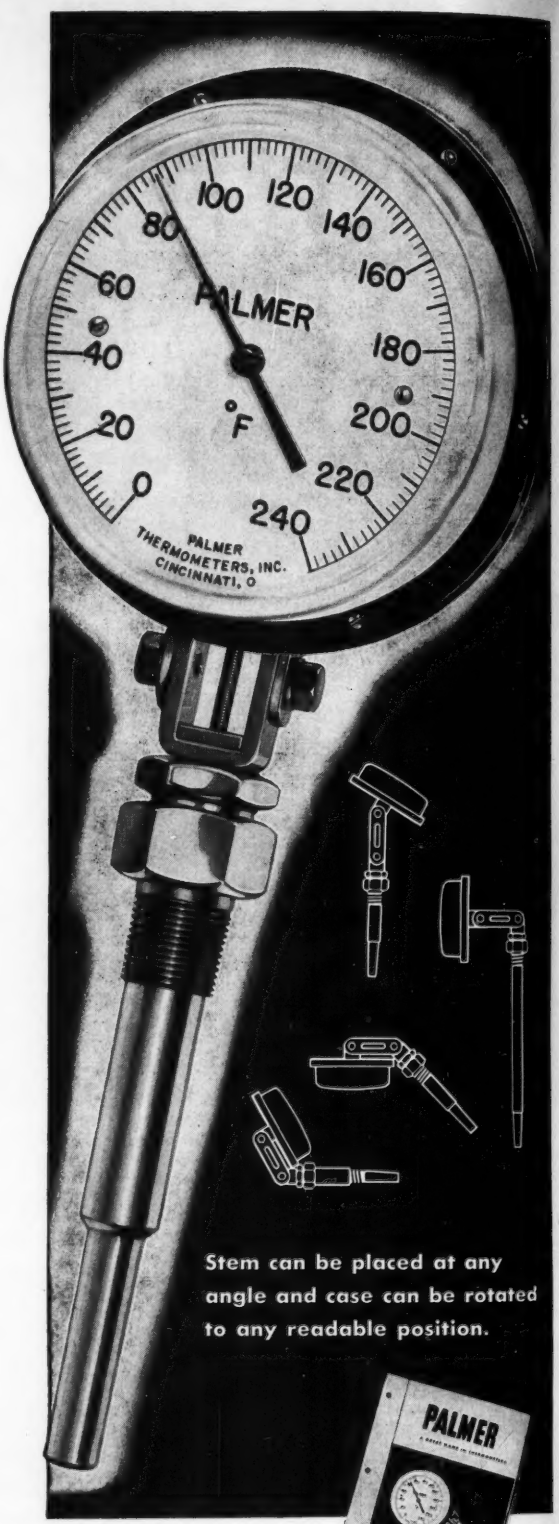
All three types have a full 4½" dial Face

for accuracy: Mercury actuated . . . Fully Compensated by Invar Compensation. Guaranteed Accurate 1 scale division.

for angularity: Can be adjusted to most readable position at any angle desired.

for readability: Bold Black Numbers . . . 11" of scale Reading Dial face can always be placed in easiest readable position.

for interchangeability: Always specify "PALMER" Separable sockets as they are interchangeable for Dial or Industrial type Thermometers.


PALMER
°F
PALMER THERMOMETERS, INC. CINCINNATI, O
Stem can be placed at any angle and case can be rotated to any readable position.
PALMER

PALMER THERMOMETERS, INC.

Mfrs. of Industrial Laboratory, Recording and Dial Thermometers

2511 NORWOOD AVE., CINCINNATI 12, O.

SEND FOR THIS BULLETIN

For details on the New Palmer Dial Thermometer, please write for Palmer Bulletin 51-129.

AMERICAN METER COMPANY'S

New Dallas Plant

New Convenience for the Southwest Area

You are cordially invited to visit our new plant and showroom at 1300 Industrial Boulevard, Dallas. Designed to specialize in the production of Orifice Meters and related equipment, it speeds deliveries and makes possible a personalized, sales-engineering service including consultations on instrument problems. The new showrooms afford complete facilities for conducting Instrument Schools for engineers and maintenance men. The complete line of American Meter Company products will also be on permanent display.

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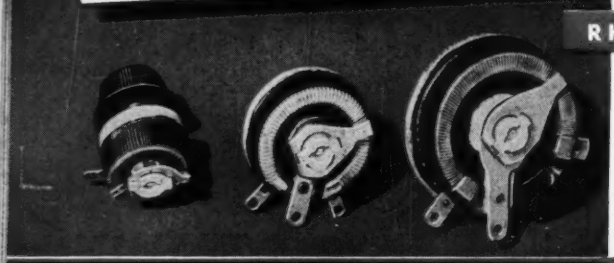
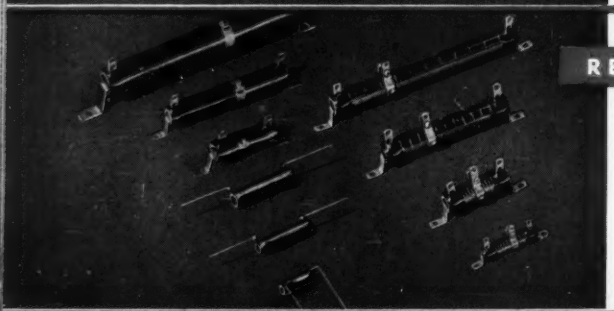
Mr. Manufacturer:

For UNFAILING DEPENDABILITY specify OHMITE Resistance Components



RHEOSTATS The Ohmite series of standard, close control rheostats is the most extensive available—so it is easy to select a size to fit your application. There are ten sizes, ranging from 25 to 1000 watts, with many standard resistance values in each size. All models have the Ohmite all-ceramic construction, with winding permanently locked in vitreous enamel, and smoothly gliding metal-graphite brush.



RESISTORS The extensive range of Ohmite types and sizes makes possible an almost endless variety of standard resistors to meet your needs. The Ohmite line includes more than 60 core sizes, in a wide range of wattage and resistance values. There are also 18 types of resistor terminals available. Included in the standard Ohmite line are fixed, adjustable, tapped, non-inductive, and precision resistors. Specially developed vitreous enamel provides years of unfailing performance.

TAP SWITCHES Ohmite tap switches are supplied in five standard models, rated at 10, 15, 25, 50, and 100 amperes, a.c. They combine high current capacity and a large number of taps with unusual compactness. Their sturdy, one-piece ceramic bodies provide permanent non-arcing insulation. Their heavy silver-to-silver contacts have a self-cleaning action and provide continuous, dependable contact with low resistance. Ohmite tap switches are supplied in enclosed or open, shorting or non-shorting types.

OTHER PRODUCTS Ohmite offers an extensive line of standard precision, non-inductive resistors in ½- and 1-watt sizes, in the standard type, vitreous-enameled type, or hermetically sealed in glass. They have an accuracy of ±1%. Ohmite non-inductive vitreous-enameled resistors are also available in standard 50-, 100-, and 160-watt sizes in a wide range of resistance values. In addition, Ohmite provides radio-frequency plate chokes, power line chokes, and dummy antennas.

Write ON COMPANY LETTERHEAD FOR CATALOG AND ENGINEERING MANUAL NO. 40

Be Right with OHMITE®

RHEOSTATS • RESISTORS • TAP SWITCHES

OHMITE MFG. CO.
4837 Flournoy St.,
Chicago 44, Ill.

Announcing...THE NEW BRUSH FAXFILM®

AN AMAZING TOOL FOR FAST STUDY AND COMPARISON OF SURFACES

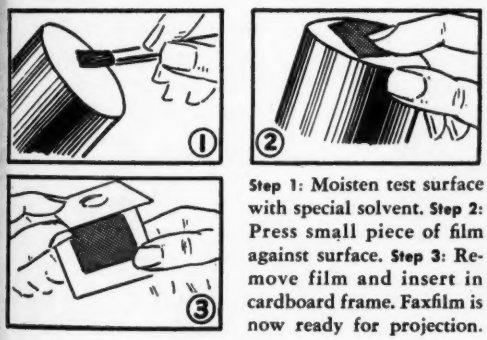
● In less than a minute you can make a reverse replica of practically any surface on Faxfilm. Then, after mounting the film and placing it in the Faxfilm projector, you can study and compare surfaces at magnifications of 30 or 100 times.

The Faxfilm projection shows roughness, wear, grain, texture, and finish of the test surface in minute detail. You can check flats, curves, cones, bores, and irregular shapes of metals, textiles, ceramics, fibers, tissues and other materials.

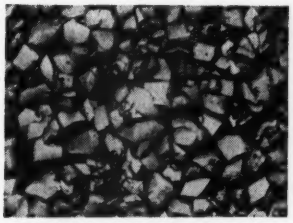
If quick information about surfaces is important to you, write for complete information now on Faxfilm. The Brush Development Co., Cleveland 14, Ohio, U.S.A. *Canadian Representatives:* A. C. Wickman (Canada) Limited, P. O. Box 9, Station N, Toronto 14, Ontario.

Faxfilm Comparison Micro-projectors and materials fit into portable carrying case at right.

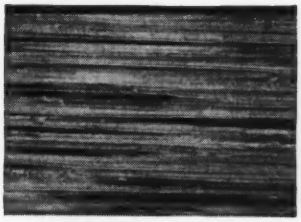
ONE MINUTE TO MAKE A TEST!



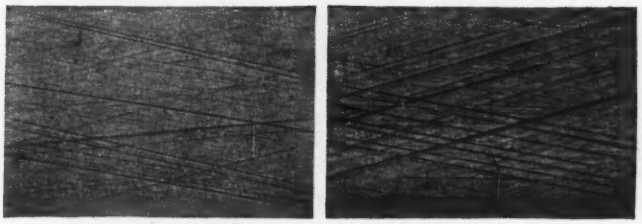
Step 1: Moisten test surface with special solvent. **Step 2:** Press small piece of film against surface. **Step 3:** Remove film and insert in cardboard frame. Faxfilm is now ready for projection.



Faxfilm projection of cylinder bore treated with Lubrite indicates uniformity of crystal size and complete coverage.



Faxfilm of steel surface with ground finish. Faxfilm is excellent for checking best speeds, feeds, and lubrication for machining.



Comparison of honed finishes in which difference in roughness is only 3 microinches RMS. (6 MU. RMS at left; 9 MU. RMS at right.)

WRITE FOR COMPLETE INFORMATION ▶

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Please send complete data on uses of Faxfilm. I would like this for: (please check)

☐ reference ☐ immediate planning

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Let's look at the performance of MOORE NULLMATIC ★

The NULLMATIC Controller was a new development in 1947. Its friction-free operation set new standards for control instruments.

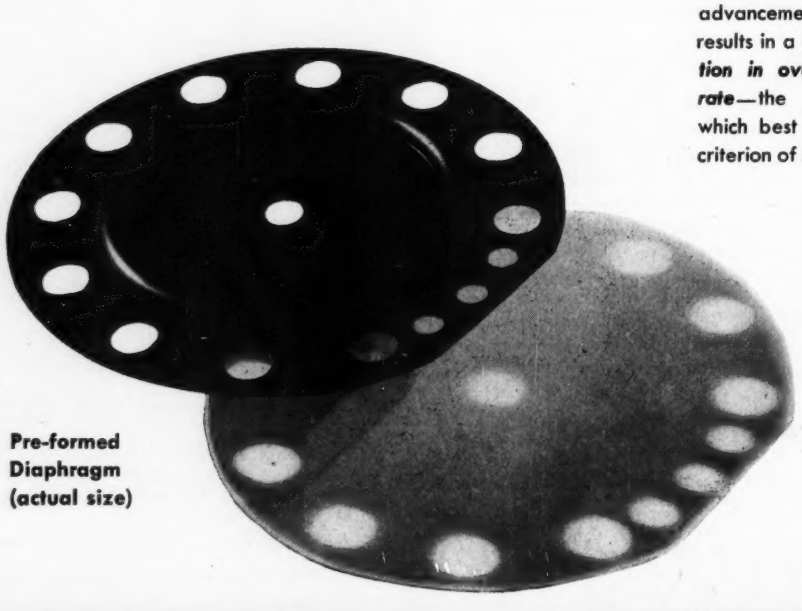
Now—***four years and 4315 Controllers later***—users here and abroad have proved the advantages of this stack-type design.

Pneumatic Force-Balance Operation
Controller lag is practically eliminated.

Simplicity of Field Maintenance
Diaphragms will withstand 100 psi. The pilot valve, restrictions, and needle valves—the only other working parts—can be removed easily, for cleaning.

Four Years of Know-How
As the result of field experience, many improvements have been made since the first production units—although *these first Controllers are still operating continuously.*

Now, the performance is further improved by the use of pre-formed diaphragms in the throttling unit. This major advancement in design results in a ***50% reduction in over-all spring rate***—the one factor which best serves as a criterion of over-all performance.



Pre-formed Diaphragm (actual size)

MOORE PRODUCTS CO., PHILADELPHIA 2

Controllers

ALL NULLMATIC Controllers meet the following performance specifications: (These values are conservative—the results of tests on standard production instruments, using 3 to 15 psi operating range and 25 psi supply pressure. Many tests have shown even better values.)

★ **RESPONSE LEVEL**

The output is sensitive to changes in the measured variable—as small as 0.01% of full range.

★ **TRACKING**

The measured variable and the control point align within 0.5% of full range.

★ **REPRODUCIBILITY OF OUTPUT**

—within 0.3% of full range.

★ **AIR CONSUMPTION**

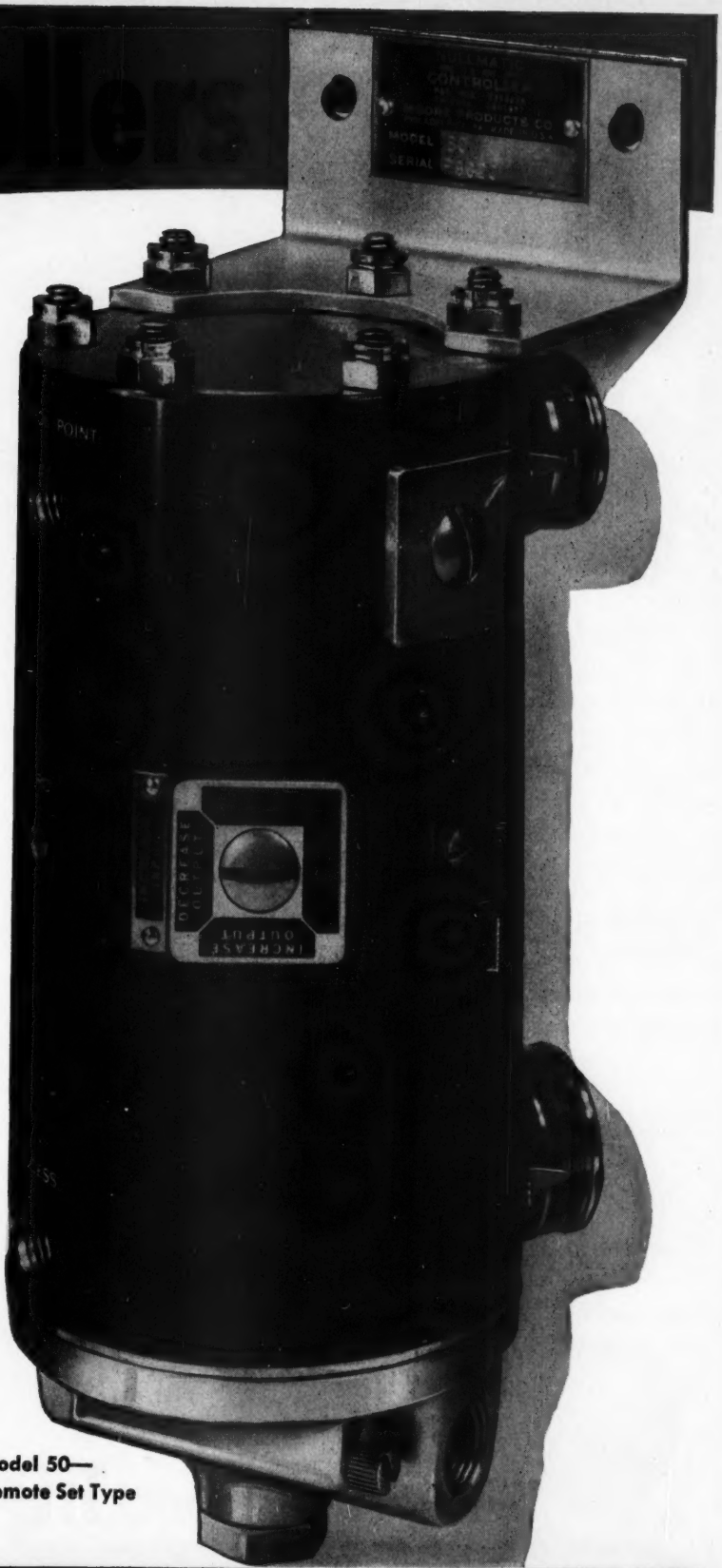
—0.2 scfm (in balance, on dead-end service).

★ **OUTPUT CAPACITY**

—up to 3 scfm.

Send for this New Catalog

Bulletin 5011 contains additional performance data and complete information on NULLMATIC Controllers, M/P Control Stations, Derivative Units, and M/F Relays for interlocking control circuits.



Model 50—
Remote Set Type

Branch Offices: CHICAGO, DETROIT, HOUSTON, LOS ANGELES, PITTSBURGH

Subsidiaries: Moore Instrument Co., Ltd., TORONTO
Air Clocks, Inc., HUNTINGTON STATION, N. Y.

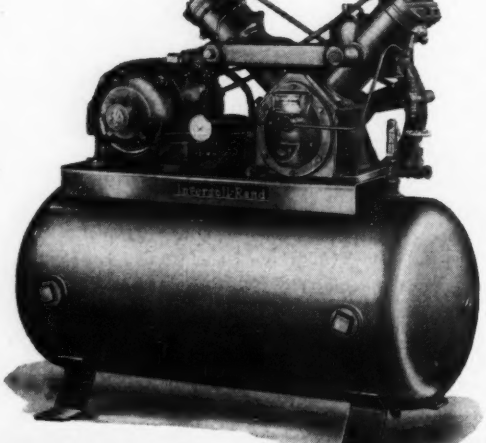
Don't Let This Trouble-Maker Deliver A Knock-Out Blow

Here's a "fixed" fight if we ever saw one! It's a fight that goes on every day. An air-operated instrument *doesn't* have much chance when a slug of oil-laden air hits it. But here's a positive way to end the production downtime and damage to instruments caused by oil slugs:

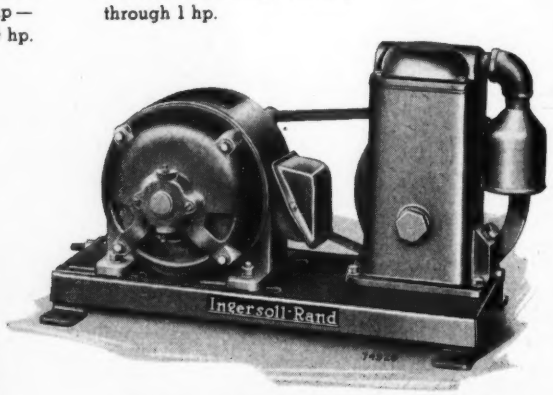
Ingersoll-Rand has perfected trouble-free air compressors that always deliver absolutely *oil-free air* to instruments. These unique non-lubricated Compressors feature pistons fitted with patented graphitic-carbon rings that prevent metallic contact of the piston with the cylinder bore. Because of the elimination of this contact, and the self-lubricating qualities of the carbon rings, the Ingersoll-Rand NL Compressor cylinders require no lubricant. Hence, there is no chance of a slug of oil ever reaching your air-operated control instruments.

Get all the facts, now. Simply contact your nearest I-R representative or write direct to Ingersoll-Rand, 11 Broadway, New York 4, New York.

Model 235 NL machines available through 3 hp—other models through 250 hp.



Model N machines available through 1 hp.



#675-3

Ingersoll-Rand

11 Broadway, New York 4, New York

NL Compressors

. . . 70 years of compressor "know-how" packed into these new compressors for air-operated instruments!

You will find *ideas in action* when you visit the Bailey Meter Exhibit, in Booth 56, at the 1951 Exposition of Chemical Industries.

For your process and power plant planning in '52 you will want the latest in measurement and control instruments. At the Bailey Exhibit you will see ways to use fuel at high efficiency—measure small rates of flow, simplify temperature measuring installations, reduce telemetering problems, brighten up plant appearance—and operate with a maximum of safety.

Your metering and control problems will be welcomed and held in the strictest confidence—come in and talk it over, or ask for a Bailey Engineer to call at your plant. G-32

These ideas for '52 will simplify and improve your process or power plant operation:

- **MINI-LINE Equipment—**
  An operating Control Console, a Model Control Room, and an Application Diagram show how you may use miniature indicators and controls to: concentrate control stations; use available manpower to best advantage; and minimize control room space requirements.
- **ARMORTUBE—**
  A flexible protected multi-tube cable which will cut your overall construction costs and improve the appearance of your pneumatic telemetering and control systems.
- **Characterized Positioning Relay—**
  A compact unit to improve performance of Control Valves and Control Drives.
- **Area Type Fluid Meter—**
  Process liquids at low rates of flow are accurately measured by this sensitive telemeter transmitter.

BAILEY METER COMPANY

1041 IVANHOE ROAD • • • CLEVELAND 10, OHIO

Controls for Processing

TEMPERATURE FLOW
PRESSURE LEVEL
% OXYGEN DENSITY
% COMBUSTIBLES RATIO

One OF A LINE....

APPROVED BY THE AIR FORCE FOR *Dependable Control*

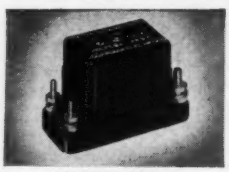
"GUARD-A-SEAL"

Guardian engineering developments of hermetically sealed aluminum containers, designed specifically for aircraft, include: The AN Connector — Screw Terminal—Lug Header — Octal Plug standard types, plus a variety built to government specifications.

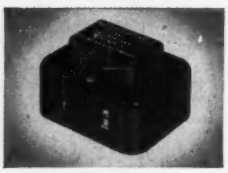
A. N. CONNECTOR

GET GUARDIAN'S NEW CATALOG OF HERMETICALLY SEALED RELAYS!

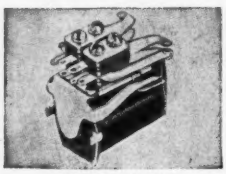
GUARDIAN RELAYS — Standard equipment in virtually all U.S. warplanes—exemplify the highest degree of *electronic precision* required by the U.S. Air Force, by government agencies and aircraft manufacturers. Guardian Relays and Solenoids—specified for timing, fusing and releasing bombs . . . firing guns . . . controlling radios . . . floodlights . . . landing gears . . . navigation aids . . . turrets . . . further establish Guardian's reputation for *electronic precision.* The Guardian Series 335 D. C. Relay, illustrated above, is but *one of a complete line* of Guardian Relays designed to permit more control in less space . . . more room for armament, power and personnel. Sensational Guardian developments include the famous "Guard-A-Seal" units specifically designed for aircraft and portable equipment, *sealed in aluminum.* They incorporate heavier frames, larger contacts, higher capacities, yet qualify under all AN weight requirements because the weight is in the relay—not the can!



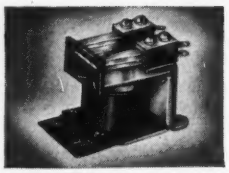
AN-3320-1 D.C.



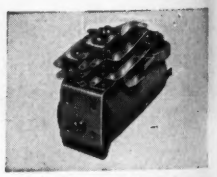
AN-3324-1 D.C.



Series 595 D.C.



Series 610 A.C.—615 D.C.



Series 695 D.C.

ALSO MINIATURE AND SUB-MINIATURE CONTROLS—WRITE

GUARDIAN ELECTRIC

1628-M W. WALNUT STREET CHICAGO 12, ILLINOIS

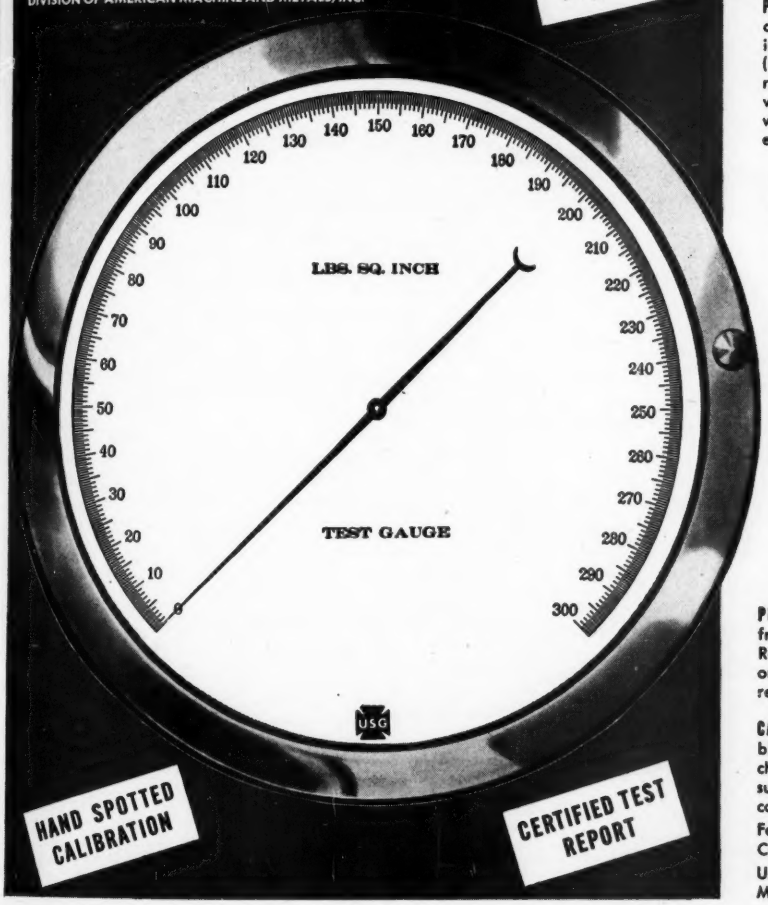
A COMPLETE LINE OF RELAYS SERVING AMERICAN INDUSTRY

"300,000 LB. CAPACITY RIEHLE COMPRESSION TESTING MACHINE, MADE BY RIEHLE TESTING MACHINE DIVISION OF AMERICAN MACHINE AND METALS, INC."

For Peak Precision

USG LABORATORY TEST GAUGES

Wherever you require *peak precision* from a gauge—for compression or tensile strength testing machines, or for replacing or supplementing dead weight testers or manometers—you can use the accuracy of USG Laboratory Test gauges to advantage.



PEAK PRECISION—½ of 1% of the indicated reading above 20% of the maximum dial range and one part in 500 (0.2%) below 20% of the maximum dial range. A Certified Test Report is furnished without charge for applying corrections when instrument is used at accuracies higher than ½ of 1% of indicated reading.

PRECISION DRAWN TUBE—Drawn from phosphor bronze, beryllium copper, or 403 stainless steel—depending on pressure range. All tubes are specially treated to produce minimum hysteresis and drift.

PRECISION MOVEMENT—Aircraft quality for highest sensitivity. Nickel-dipped bronze with extra long bearings and heavy bronze bushing fitted with nickel silver pinions and arbors.

PRECISION CALIBRATION—Graduations are individually hand-spotted and engraved on a white background. Dial may be rotated 10° for zero adjustment to compensate for preloading.

DIAL SIZES—12" and 16".

PRESSURE RANGES—All pressure ranges from 30" Vacuum and 15 to 20,000 p.s.i. Ranges over 30,000 p.s.i. on special order. Suppressed scales available on request.

CASE AND RING—Cast aluminum case, black finish. Cast brass ring with polished chromium finish. Flush panel mounting or surface mounting with back or lower connection.

For additional information, write for USG Catalog 64.

United States Gauge, Division of American Machine and Metals, Inc., Sellersville, Pa.

Quality Gauges Engineered for Enduring Accuracy UNITED STATES GAUGE

PRODUCTS OF UNITED STATES GAUGE . . . Absolute Pressure Gauges • Aircraft Instruments • Air Volume Controls • Altitude Gauges • Boiler Gauges Chemical Gauges • Mercury, Gas, and Vapor Dial Thermometers • Glass Tube and Industrial Thermometers • Flow Meters • Inspectors' Test Gauges Precision Laboratory Test Gauges • Marine, Ship and Air-Brake Gauges • Voltmeters • Ammeters • Welding Gauges.

OTHER DIVISIONS OF AMERICAN MACHINE AND METALS, INC. AT SELLERSVILLE, PA.: GOTHAM INSTRUMENTS, AND AUTOBAR SYSTEMS.

memo to the trade:

THE ARNOLD ENGINEERING COMPANY offers a complete line of MAGNETIC MATERIALS produced to the highest quality standards

PERMANENT MAGNET MATERIALS

- Cast Magnets, Alnico I, II, III, IV, V, VI, XII, X-900
- Sintered Magnets, Alnico II, IV, V, VI, X-900, Remalloy*
- Vicalloy* • Remalloy* (Comol)
- Cunico • Cunife • Cast Cobalt Magnet Steel

HIGH PERMEABILITY MATERIALS

TAPE WOUND CORES

- Deltamax • Supermalloy* • Permalloy* • 4750 • Mumetal

POWDER MO-PERMALLOY* CORES

PERMENDUR,* Cast and Forged

*Manufactured under license arrangements with WESTERN ELECTRIC COMPANY

Write for information on any of these Magnetic Materials

WAD 5679

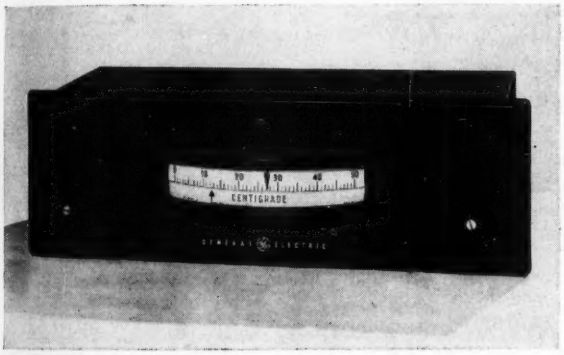
AL ARNOLD

THE ARNOLD ENGINEERING COMPANY

SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION

General Office & Plant: Marengo, Illinois

New G-E resistance thermometers accurately indicate and control low temperatures



FOUR TYPES AVAILABLE—indicators, protectors, and two- or three-position controllers—for either flush or surface mounting.

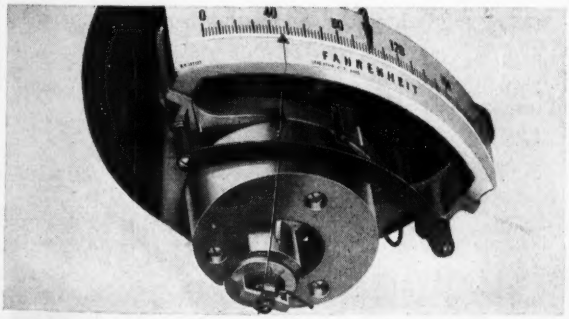
TEMPERATURES FROM −100 F TO +300 F can now be accurately indicated and controlled with General Electric's new line of resistance thermometers. They indicate accurately within ½ of 1 per cent full scale. Any change in temperature equivalent to 1/10 of 1 per cent full scale starts immediate control action.

Normal changes in humidity or room temperature do not affect the exactness of control. Neither does a change in control voltage. Sturdy, simple construction assures reliable operation under severe operating conditions.

NARROW TEMPERATURE SPANS, as small as 90 degrees, are available anywhere in the −100 F to +300 F range. For complete information, contact your nearest G-E representative or write Section 602-224 for Bulletin GEC-835. General Electric, Schenectady 5, New York.

GENERAL ELECTRIC

602-224

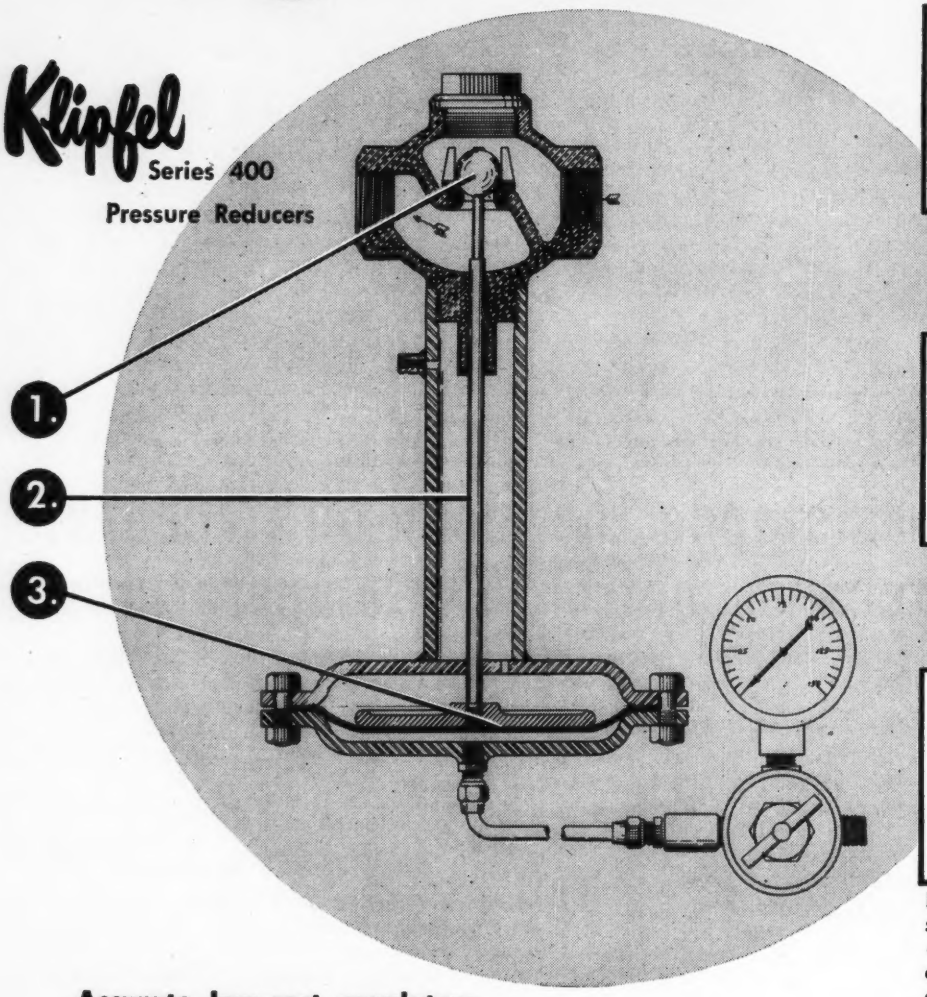


RATIO-TYPE MECHANISM stands up against hard usage and holds accuracy despite shock and vibration. Sturdy construction assures dependable service and also fewer maintenance problems.

ADJUSTING SET POINT of Type HP-13 resistance thermometer is quick and easy. New General Electric instrument provides high sensitivity and accuracy, yet is simply and sturdily constructed.

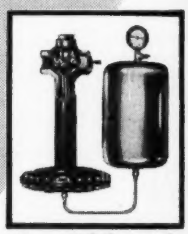
only 3 moving parts

Klipfel Series 400 Pressure Reducers



No. 432 with constant air supply—for quick, easy adjustment.

No. 431 with air dome—for isolated installations.



No. 430 with separate air tank—for variable ambient temperature.

Accurate low-cost regulators . . .

FOR longer service with negligible maintenance, operating parts are reduced to just three, inner valve, stem and diaphragm, in the Klipfel 400 Series air-loaded Pressure Reducing Valves. In addition, these 400 Series Valves provide exceptionally close regulation for an unusually low initial cost.

The stainless steel ball inner valve is a perfect sphere, extremely hard and well guided to close to a tight seat. Easily reseated if necessary . . . is self-cleansing and non-sticking. Diaphragm is always in balance . . . no stress, no bursting. Regulation is accurate and easily controlled. For increased safety, flow automatically shuts off in case of diaphragm failure.

For full data on the Klipfel 400 Series Valves, for steam, air, water or gas, write Dept. DA-11 for Bulletin No. 148.

Klipfel VALVES INCORPORATED

DIVISION OF HAMILTON-THOMAS CORP., HAMILTON, OHIO

SWIFT, SURE FREQUENCY COMPARISON

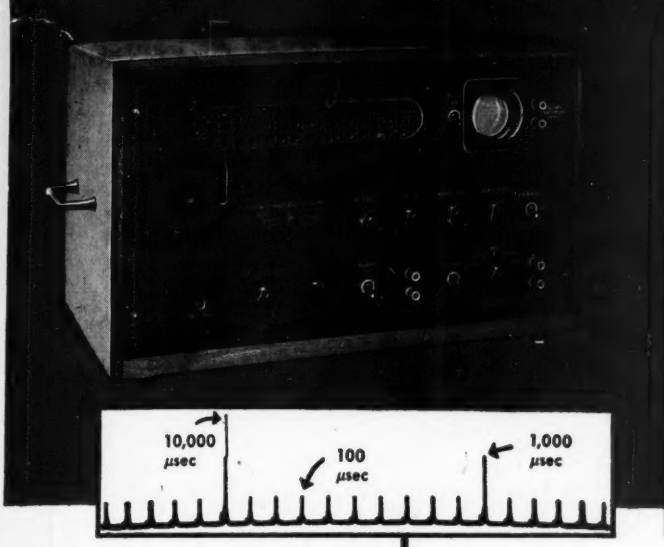


FIG. 1. Timing Comb, -hp- Model 100D

NEW hp SECONDARY FREQUENCY STANDARDS

MODELS 100C AND 100D

- Sine or rectangular waves
- 100 μsec time markers
- Built-in oscilloscope
- Stability 1/1,000,000
- Low output impedance
- New, improved circuits
- Audio, supersonic, rf measurements

SPECIFICATIONS

-hp- 100D Secondary Frequency Standard

Accuracy:
About 2 parts per million per week, normal room temperature.

Stability:
About 1 part per million over short intervals.

Output:
Controlled frequencies: 100 kc, 10 kc, 1 kc, 100 cps, 10 cps. Sine or rectangular waves; marker pips. Internal impedance approx. 200 ohms.

Wave Shape:
Sine wave: less than 4% distortion into 5,000 ohms or higher load.

Marker Pips:
10,000, 1,000 and 100 μsec intervals.

Oscilloscope:
Integral with circuit. Establishes 10:1 Lisajous figures to show division ratio. May be used independently of standard.

-hp- 100C Secondary Frequency Standard

Accuracy:
Within ± .001% normal room temperature.

Output:
Controlled frequencies of 100 kc, 10 kc, 1 kc, and 100 cps. Internal impedance approx. 200 ohms.

Wave Shape:
Sinusoidal only. 4% distortion into 5,000 ohm load.

Power Supply:
(100C and 100D) 115 v, 50/60 cps, regulated to minimize line voltage fluctuations. Power drawn approx. 150 watts.

Mounting:
(100C and 100D) Cabinet or relay rack. Panel 19" x 10½". 12" deep.

Data Subject to Change Without Notice

The new *-hp-* 100C and 100D Secondary Frequency Standards incorporate all the features of the time-tested *-hp-* models 100A and 100B, plus important new advantages including rectangular wave output, timing pips, and an internal oscilloscope for convenient frequency comparison. The *-hp-* 100D may be conveniently standardized against station WWV with a minimum of external equipment, and thus provide most of the advantages of an expensive primary standard.

Crystal Controlled Frequencies

The new *-hp-* Models 100D and 100C employ a crystal-controlled oscillator and divider circuits offering a new high in stability and simplicity of operation. Standard frequencies are available through a panel selector switch, and may be employed simultaneously. Internal impedance is low (about 200 ohms), so that standard frequencies can be delivered at some distance from the instrument.

The *-hp-* 100D Secondary Frequency Standard offers sine waves at 5 frequencies and rectangular waves at 4 frequencies, plus a built-in oscilloscope. The instrument also provides a timing comb with markers 100, 1,000 and 10,000 microsecond intervals. Rectangular wave output has a rise time of approximately 5 microseconds. Accuracy is 2 parts per million.

5 v. at all Frequencies

The more moderately priced *-hp-* 100C Standard offers sinusoidal frequencies at 4 crystal-controlled frequencies and, like the *-hp-* 100D, provides 5 volts of output at all frequencies. Accuracy .001%.

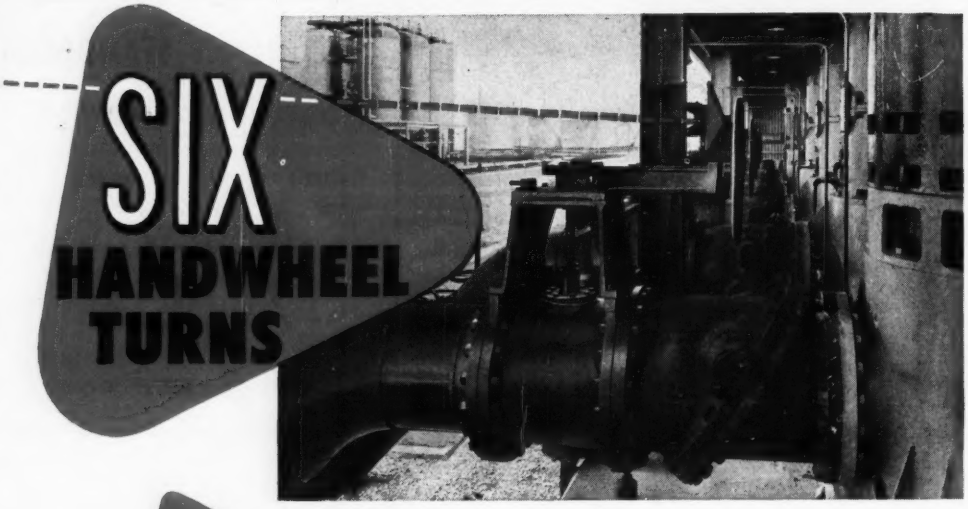
Both models operate from a 115 v. ac power supply, and power is regulated to minimize power line voltage fluctuations.

Get full details . . . see your -hp- representative or write direct . . . today!

HEWLETT-PACKARD CO.
1977C Page Mill Road ● Palo Alto, Calif.
Export: FRAZAR & HANSEN, LTD.
301 Clay Street, San Francisco, Calif., U. S. A.
Offices: New York, N. Y.; Los Angeles, Calif.

R-S valvEvents

• EXCERPTS FROM THE R-S BOOK OF EXPERIENCE •



. . . Operate these R-S Valves

This installation of twenty-inch valves in the water system to one of the large oil refineries in Louisiana is another example of R-S time-saving efficiency. Such ease of operation is an important consideration in any pumping operation and especially where a battery of synchronous driven pumps discharges into a common header. Burned-out motors at start-ups can be practically eliminated.

Substantial savings in pumping power result due to the low pressure drop. The beveled vane ordinarily seated at a 12½° angle means greater control rangeability either manual or automatic and no down-time for cleaning.

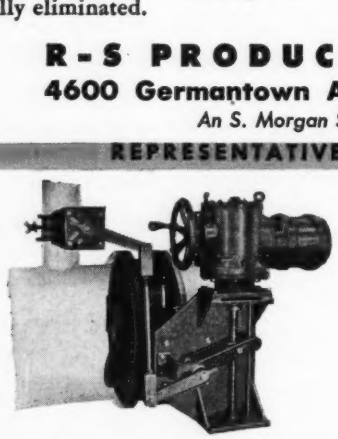
Install easily operated R-S Valves and obtain the most from your valve investment. Your local R-S representative is a valve expert—know him well.

R-S PRODUCTS CORPORATION

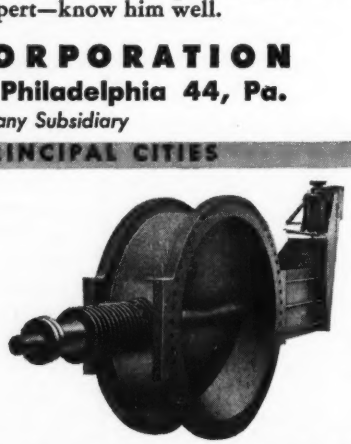
4600 Germantown Avenue, Philadelphia 44, Pa.

An S. Morgan Smith Company Subsidiary

REPRESENTATIVES IN PRINCIPAL CITIES



No. 798—Thirty-six inch and eight-inch R-S heavy duty valves of R-S "H" Metal at elevated temperatures for foundry cupola control. When the larger valve is wide open, the smaller valve is fully closed and vice versa. Slow operation is required, hence the motor operator with threaded reachrod.



No. 735—72-inch 125-pound "H" Metal R-S Valve for elevated temperatures. Valve is equipped with dual cooling fins. Oil cylinder and positioner utilizes 200 psig oil and 0-15 psig instrument air. Positioner cam driven simulating straight line semi-log control curve.

MEMO

The Hagan Ring Balance Dual Meter is the most adaptable flow meter made . . .

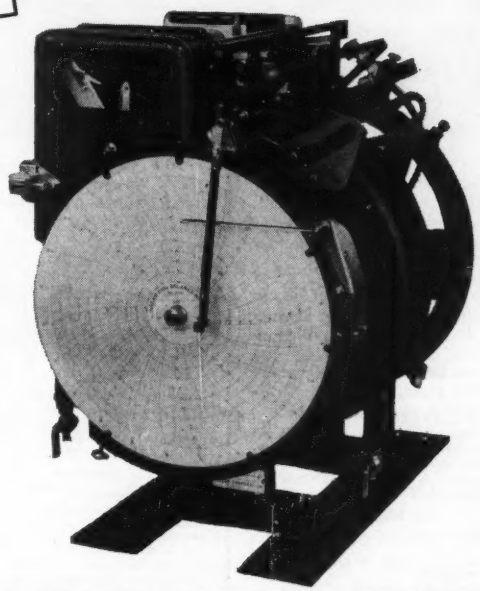
and here are four typical applications:

1. **MEASURE TWO INDEPENDENT FLOWS:** The Hagan Ring Balance Dual Ring Flow Meter will record two rates of flow on one chart, as, for example, steam flow and air flow, or gas flow and air flow.

2. **MEASURE TWO FLOWS SEPARATELY, ADD AUTOMATICALLY:** The Hagan Ring Balance Dual Ring Flow Meter will record flows from two separate lines, and integrate and record the total flow.

3. **MEASURE TWO FLOWS SEPARATELY, SUBTRACT AUTOMATICALLY:** For split flows, The Hagan Ring Balance Dual Ring Flow Meter will measure the main flow and the flow through one branch, record these flows and the difference between them, (this difference being the flow through the second branch), and will integrate any two flows automatically.

4. **FLOW MEASUREMENT CORRECTIONS AUTOMATICALLY MADE ON BASIS OF GRAVITY OR DENSITY:** One unit of the Hagan Ring Balance Dual Ring Flow Meter measures flow, the other measures gravity of a liquid or gas density. Records may show corrected or uncorrected flow rates, gravity or density measurement, with automatic integration of either flow rate.



The Hagan Ring Balance Dual Ring Flow Meter may also be compensated automatically for temperature and pressure factors.

For information on how Hagan Ring Balance Meters can solve your particular metering problem, write to Hagan Corporation, Hagan Building, Pittsburgh 30, Pa.

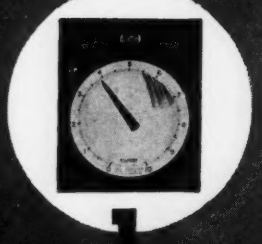
HAGAN CORPORATION

RING BALANCE FLOW AND PRESSURE INSTRUMENTS
THRUSTORQ FORCE MEASURING DEVICES
BOILER COMBUSTION CONTROL SYSTEMS
METALLURGICAL FURNACE CONTROL SYSTEMS

4 ways to know your combustion efficiency

The ever-increasing pressure for fuel economy makes some type of "combustion guide" instrument an essential part of any modern fuel burning operation. Hays offers the most complete line of such instruments in the industry—adaptable to your cost and engineering requirements. Your particular needs with regard to price, accuracy, speed of response, etc., will determine your choice—*however, whatever your needs, Hays has the instrument.*

Select your combustion guides *from the most complete line in the industry*



1

HAYS MAGNOTHERM O_2 METER

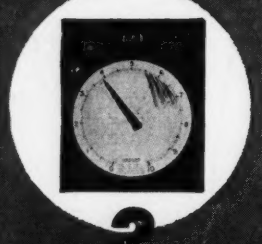
Measures fundamental indicator of combustion efficiency —Oxygen. Electronic in operation, with all of the most advanced features incorporated into its design, it is applicable not only to power plant conditions but also to a host of process problems such as catalytic crackers, open hearths, process heaters, inert gases, etc.

PRINCIPLE

Based on paramagnetic (attracted by magnetism) properties of oxygen. All other gases usually encountered are slightly diamagnetic (repelled by magnetism).

FEATURES

Highly sensitive to change in O_2 content
Rapid response to change in O_2 content
Electrically operated
Electronic type recorder
Temperature controlled
Pressure compensated
No liquid or gaseous fuel required to be added
No chemicals
High accuracy maintained
Not affected by wide change of gas flow rate
Continuous sampling and recording
Glass and corrosive resistant sampling system
Remote mounted analyzer
Remote mounted recorder
12" 24-hour chart
O_2 recorder and indicator
4 records on same chart possible
Low maintenance



2

HAYS CONDU-THERM CO_2 METER

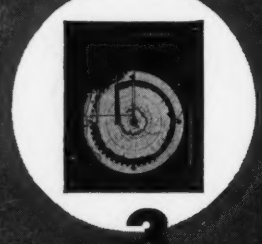
Meter incorporates all of the construction and manufacturing ideas which Hays has developed during many years of experience in gas analysis. A deluxe instrument, the Condu-Therm CO_2 Analyzer is especially applicable to the larger boiler plants and to industrial processes.

PRINCIPLE

The principle of operation used in the Hays Condu-Therm Meter is that of thermal conductivity of gases, i.e., that all gases conduct heat at different rates.

FEATURES

Electrically operated
Electronic type recorder
Temperature controlled
Humidity controlled
No chemicals required
No moving parts in analyzer
Continuous sampling
No drying agent required
Easily installed glass and corrosion resisting sampling system
Not affected by wide change in gas flow rate
Rapid response
High sensitivity
Continuous recording
Remote mounted analyzer
Remote mounted recorder
12" 24-hour chart
CO_2 Recorder and Indicator
As many as 4 records on same chart
Low maintenance



3

HAYS COMBUSTION [illegible]

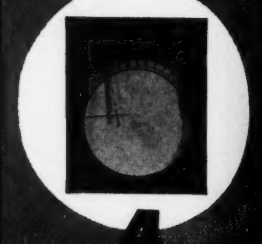
Hundreds of these meters have been in operation for many years in all types of plants burning all kinds of fuels and saving thousands of fuel dollars.

PRINCIPLE

Operates on Orsat principle of Volumetric measurement and chemical absorption. Extremely simple: sample of flue gas trapped and accurately measured; passed through chemical which removes CO_2 component of gas mixture. Sample is re-measured, volume compared to original sample. Difference before and after absorption gives exact percentage of CO_2 absorbed by chemical.

FEATURES

Low price
Water operation
Pressure and temp. compensated
Volumetric determination
Chemical absorption
2 minute operating cycle
Easily understood
Rugged construction
Low maintenance
Available in 6 remote mounted types and 3 integral types
Remote or integral mounting
10" 24-hour chart
Available for: (a) CO_2 only—recording with or without indicator (b) CO_2 and flue gas temperature recorder combined (c) CO_2, draft or flue gas temperature recorder combined



4

HAYS-PENN BOILER [illegible] METER

Provides a QUANTITATIVE guide to efficiency — deals with quantities of air and steam; by contrast CO_2 and O_2 meters are QUALITATIVE guides since they determine directly quality of combustion gases. Both Boiler Efficiency Meter and Gas Analysis Meter are used to obtain advantages of both methods.

PRINCIPLE

Pounds of air required to burn each pound of coal vary widely with heating value of coal; constant weight of air is required to produce same Btu. Similar relationship exists when oil and natural gas are used as fuels. Record of steam flow is assumed to be Btu's produced; record of air flow is calibrated to flow of air required to generate that steam.

FEATURES

Electric operation of flow meter and air flow recorder
Diaphragm type air flow measuring unit
Air flow measuring element does no work
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Adjustable cam air flow calibration
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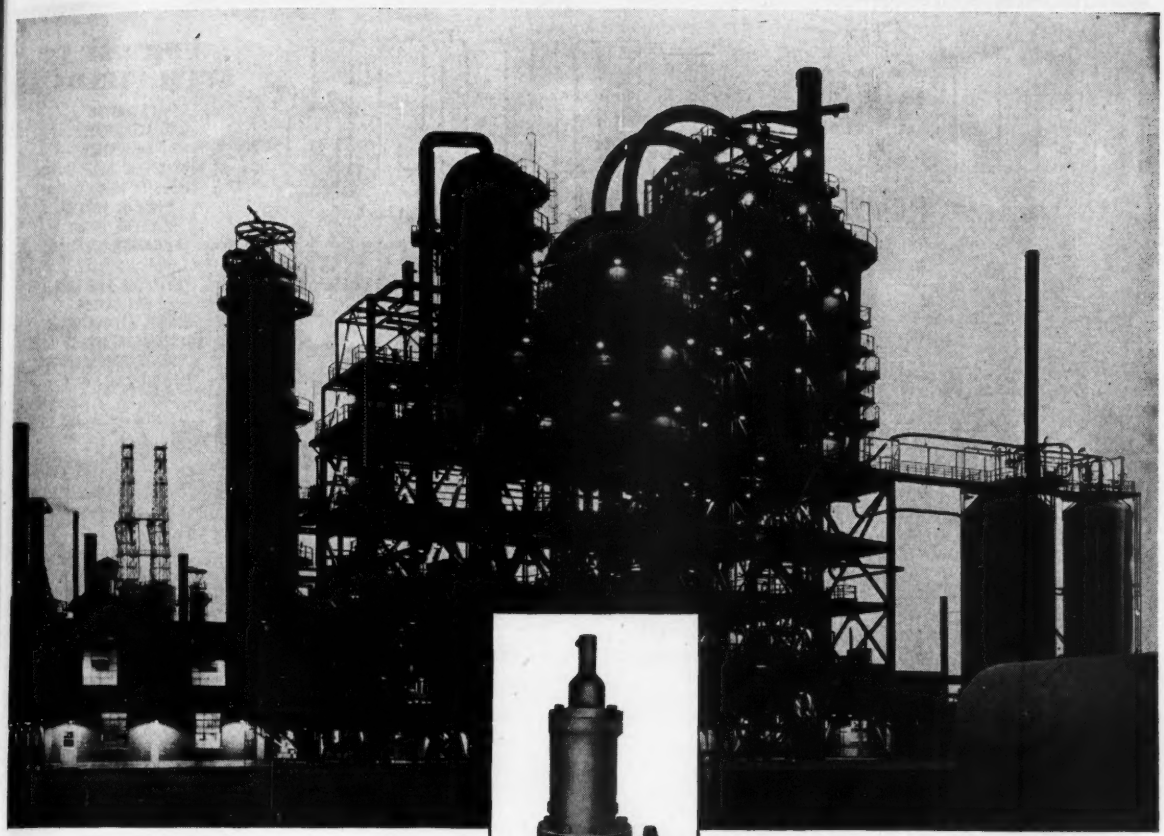

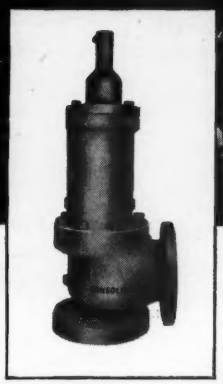

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Leakage under discharge piping stresses is eliminated because of the outside bevel seat and floating guide construction of these valves. The method of establishing the outside bevel seat permits the disc to be moved on a radial seating surface. Complete tightness is assured in all positions within the deflection range, under all conditions of service.

Designed with 25% fewer parts, Consolidated Safety Relief Valves simplify servicing, minimize standardization problems, reduce maintenance costs. Working parts cannot become misaligned — continuous performance is assured at the rated capacity.

Growing defense and civilian needs are crowding refinery capacity. So—depend on Consolidated Safety Relief Valves to help you stretch the time between turnarounds. There's no better valve investment to safeguard life, property and continuous production. Your local distributor will gladly tell you all about these economical, long-life safety relief valves.

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CONSOLIDATED SAFETY RELIEF VALVES

MAXWELL MANNING & MOORE INC. TRADE MARK

A product of **MANNING, MAXWELL & MOORE, INC.** TULSA, OKLAHOMA

MAKERS OF 'CONSOLIDATED' SAFETY AND RELIEF VALVES, 'AMERICAN' INDUSTRIAL INSTRUMENTS, 'HANCOCK' VALVES, 'ASHCROFT' GAUGES. BUILDERS OF "SHAW-BOX" CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES.

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The controlling unit of these frequency standards is a bi-metallic fork, temperature-compensated and hermetically sealed against humidity and variations in barometric pressure. When combined with related equipment, accurate speed and time controls are afforded by mechanical, electrical, acoustical or optical means.

Instruments of our manufacture are used extensively by industry and government departments on such precision work as bomb sights and fire control.

Whatever your frequency problems may be, our engineers are ready to cooperate.

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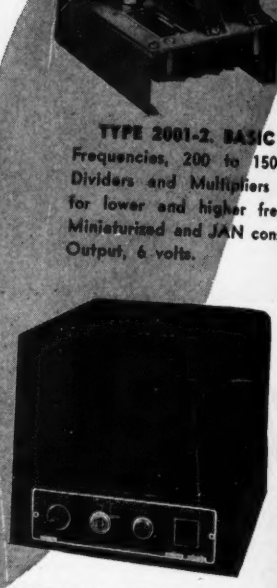

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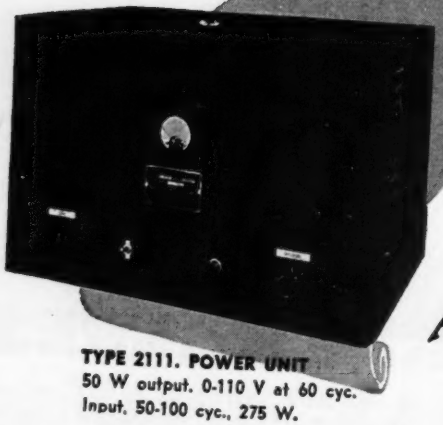
TYPE 2121A. LAB. STANDARD
Outputs, 60 cycle, 0-110 Volts. 120-240 cycle impulses.
Input, 50-400 cycles, 45 W.



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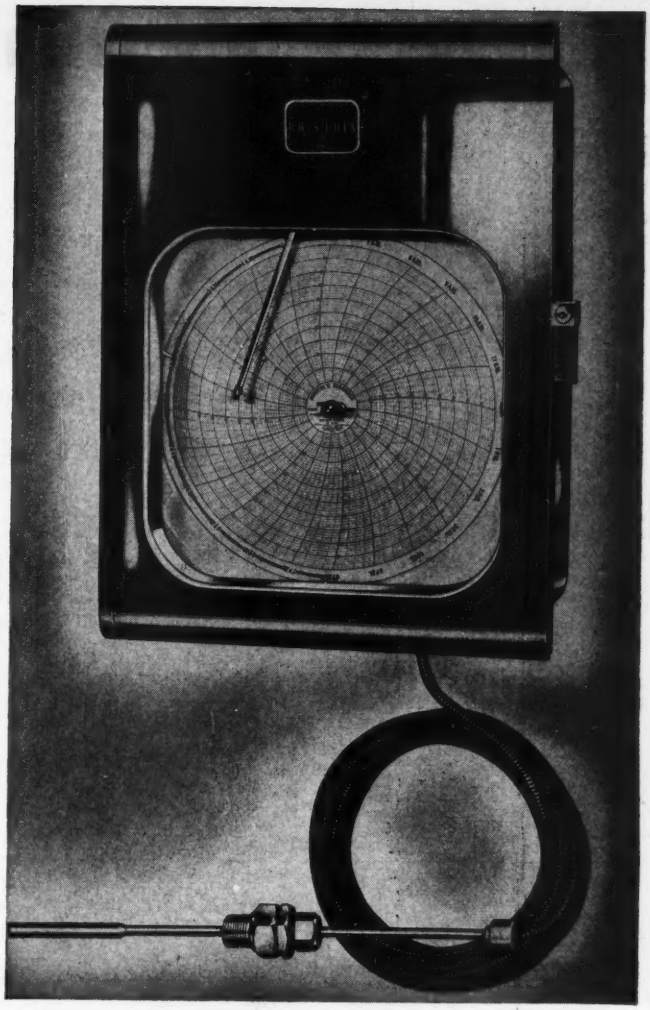
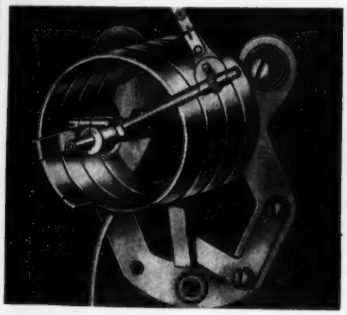
NEW SERIES 500 RECORDING THERMOMETER CARRIES ON THE BRISTOL TRADITION



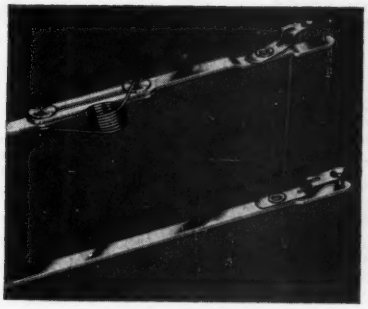
The Bristol Series 500 Recording Thermometer for temperatures between minus 125 F and 1000 F incorporates every modern improvement for dependable accuracy, ease of use and convenient servicing.

In addition, it represents all the wealth of thermometer "know-how" gained by nearly 60 years of experience in building hundreds of thousands of recording thermometers—known all over the world for their high accuracy and dependability.

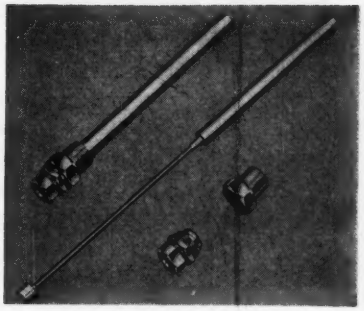
Send for the new Thermometer Catalog T840. Address THE BRISTOL COMPANY, 113 Bristol Road, Waterbury 20, Conn.



MORE SECURELY SEALED—TROUBLE-FREE—The measuring system is securely sealed against leakage. Parts are joined with silver solder by induction heating.



STURDY, FRICTION-FREE CONNECTION between measuring element and pen arm mechanism is provided by strong, adjustable links with polished stainless steel pins.



FLEXIBLE ARMOR is interlock-type, withstands heaviest abuse. *Bulbs*—plain, union or socket type—easily converted.

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Doubled Output with Type H Leak Detector

Production was doubled when the Lintern Corporation, Berea, Ohio, adopted General Electric's new Type H Leak Detector on its manufacturing line. The Leak Detector is used to test gasoline tanks to make sure no leaks exist.

"The new instrument enables the company to detect the smallest of leaks in a tank and these can be repaired before the unit is shipped," Lintern engineers said.

- **Instantly detects leaks in pressure systems***
- **Provides portable, lightweight inspection**
- **Eliminates immersion and storage tests**

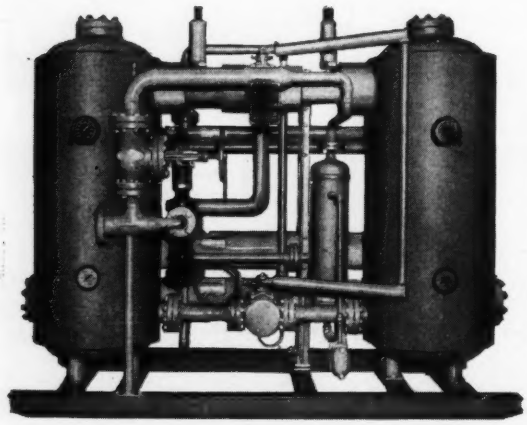
***If the system is filled with combustible gas, write for special application information.**

$519.00 list price

Order your Type H Leak Detector through your nearest G-E Sales Office, or write Sect. 687-78, Special Products Division, General Electric Company, Schenectady, N. Y.

GENERAL ELECTRIC

687-78



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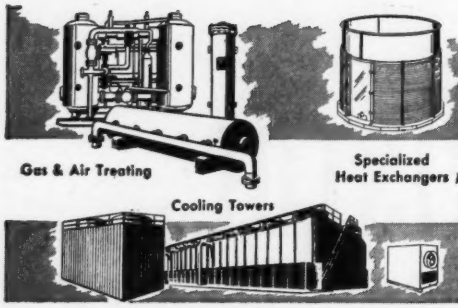

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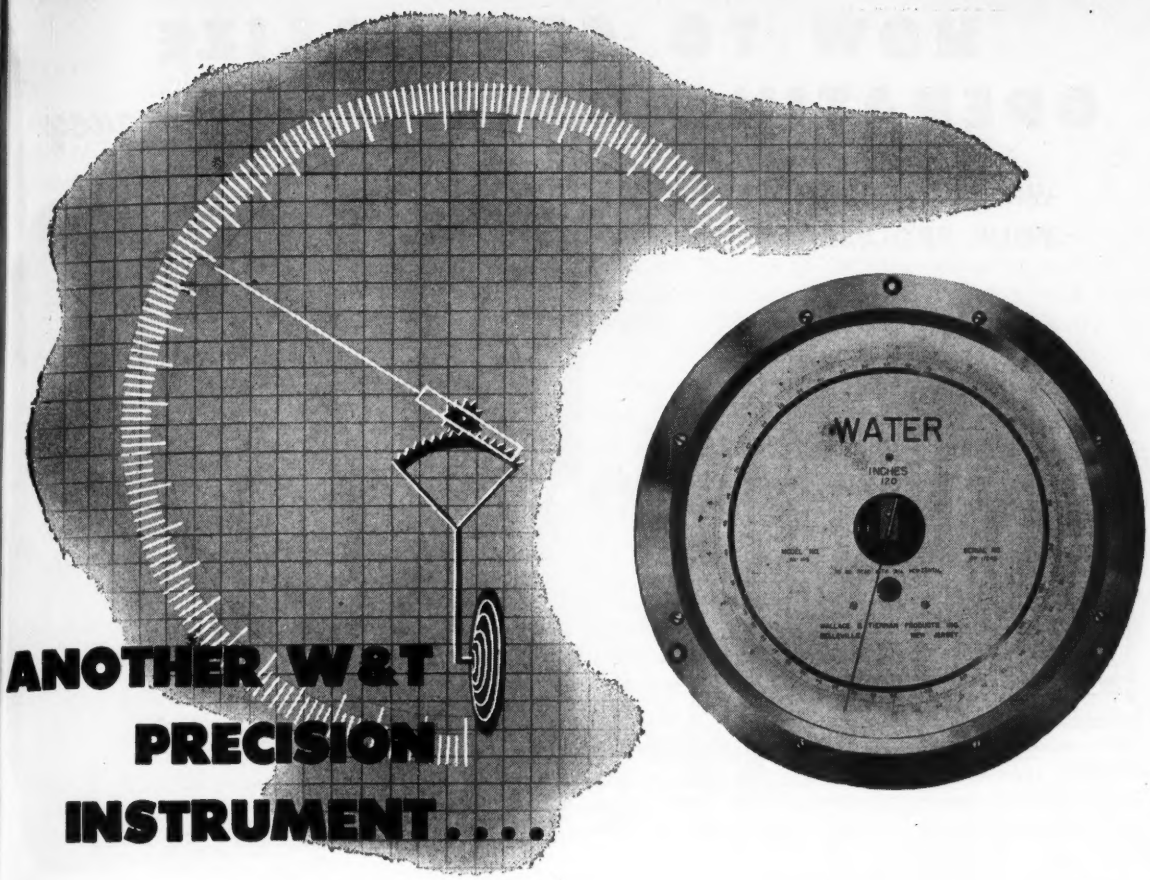

ANOTHER W&T PRECISION INSTRUMENT....

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The W&T Precision Dial Manometer answers the problem of conveniently measuring pressure with a sensitivity of 1 part in 10,000.

This sturdy, compact instrument, which is widely used for wind tunnel work, power plant test stands and in gas turbine testing, has a large easy-to-read dial. It is custom calibrated in *any* pressure units over various ranges up to a maximum of 200 inches of mercury.

In addition, the W&T Precision Dial Manometer possesses these outstanding advantages:

Accuracy .....1 part in 1000
Scale length.....45"
Case .....pressure tight, metal for flush mounting.
Full protection against over pressure.
Measures gauge pressure, vacuum and differential pressure.

This instrument with its sensitive response and precision results is typical of a wide variety of pressure instruments of all types — from low pressure indicators to altimeters — manufactured by W&T. If you have a problem in pressure measurement, write, telling us the details. We'll be glad to help.

WALLACE & TIERNAN
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ELECTRICAL MECHANISMS AND PRECISION INSTRUMENTS
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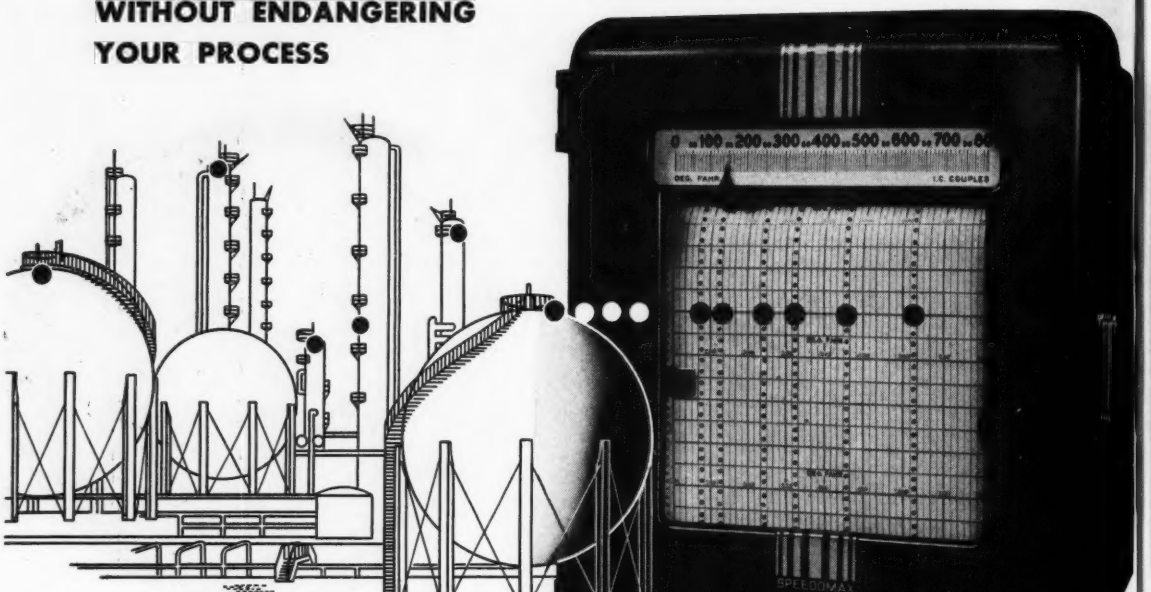
HOW TO CENTRALIZE OPERATING DATA *and save money*

WITHOUT ENDANGERING YOUR PROCESS



In as little time as 2 seconds per point, Speedomax Multiple-Point Recorders centralize data about temperatures or other conditions scattered throughout process units.

Centralizing operating data from process units on one recording instrument pays off. It saves panel space. It lowers the recording cost per point. It warns of upsets in ample time for your men to act. It does all this . . . IF the instrument checks operating conditions frequently enough—fast enough.

With Speedomax Multiple-Point Recorders, you get not only the inherent savings in centralized data, but maximum information about critical process operations. At the fast rate of 2 seconds per point (or 3 or 4 seconds, if preferred), they can whip through as many as 16 or 20 similar variables in as little as 32 or 40 seconds. Where an extremely critical variable is involved, that point can be recorded more frequently than the others —in the sequence of 1, 2, 1, 3, 1, 4, 1, 5, etc.

In addition to this recording speed, other features give superior performance. A soundly-designed amplifier and electronic circuit assure unusual accuracy and sensitivity over range spans as narrow as 100 F. Instrument performance is unaffected by vibration. The quantity measured may be temperature, pH, speed, weight or electrical load.

The next time you want to bring temperatures or other data to a central point, make sure you do it safely . . . by getting the speed you need to guard against sudden upsets. Specify Speedomax Multiple-Point Recorders. For additional information about these instruments, just check the coupon and return.

LEEDS & NORTHRUP CO.

LEEDS & NORTHRUP CO.
4955 Stenton Ave., Phila. 44, Pa.

Please send Speedomax Catalog ND46.
Please send information about applying Speedomax Multiple-Point Recorders to

(Name) (Title)
(Firm)
(Address)

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An Open Letter to Charles Wilson

Charles E. Wilson, Director
Office of Defense Mobilization
Washington, D. C.
Dear Sir:

Your third quarterly report to the president, called "Three Keys to Strength," directs attention to the fact that military production must be increased, that the economic stability of the nation must be maintained by precluding further inflation, and that skilled-labor shortages must be overcome. Therefore, I want to direct your attention to a method for (1) increasing production, (2) decreasing costs, and (3) reducing the labor content of products—*all at the same time.* The method to which I am referring is increased use of *instrumentation.*

Instruments in industry relieve skilled operators, permit one skilled operator to perform many functions, and operate in general as the eyes, ears, and brains of industry. Instruments make possible the 24-hour operation of complex processes with minimum operational personnel. Instruments are a relatively inexpensive means by which production can be increased without increasing either the labor content of the manufactured article or the inflationary pressure on the economy.

Industrial executives have recently become aware of the tremendous importance of instruments. However, recognition of the power of instrumentation in cutting manufacturing costs, reducing waste and rejects, maintaining product quality, and providing greater production per man-hour, is not yet nation-wide. Therefore, I am not completely surprised to find no mention of instruments in your third quarterly report—*despite the fact that no other single means can advance all the main points in your program at one time.*

Increased use of instruments for measurement and control is vital if production is to be increased simultaneously with reduced labor content and manufacturing costs. An increase in instrument production might be less of a bottleneck than an increase in many other items because of the small amount of vital materials needed for instrument production. An advisor on instrumentation, operating from your office, could be one effective way in assisting industry with the "know-how" of instrument application to specific problems, and in promoting greater production of instruments.

Very truly yours,
INSTRUMENTS PUBLISHING COMPANY
RICHARD RIMBACH, *Publisher*

An Open Letter to Production Men

Each member of the Production Staff
American Industry, Inc.
Dear Sir:

You are being requested to produce 50 billion dollars of military equipment in 1952 and yet produce enough consumer goods to check inflation.

You cannot do this by increasing your labor costs; this is inflationary. You cannot do this by building larger plants like the ones you already have; this also is inflationary.

The only way you can do the job is to increase your efficiency and production without increasing your labor costs.

Fortunately, there is a way to do this. Every industrial operation can be run more efficiently by *instrumentation.* You can cut costs, duplicate results, and reduce waste—by *instrumentation.* You can record your operations, isolate operational factors, and account for all costs—by *instrumentation.*

The survival of a way of life depends in part on your response to the demand to produce and produce —without inflation. The instruments to do the job are available to you. Use them.

Very truly yours,
INSTRUMENTS PUBLISHING COMPANY
RICHARD RIMBACH, *Publisher*

The Instruments Publishing Company feels that the message contained in the letters above is of such importance that it is currently running a series of twelve full-page advertisements in *Dun's Review*, the purpose of which is to bring this message to industrial executives and financiers. See page 1359 for a reprint of the ad which appeared in the July issue of *Dun's Review*.

The HUMAN FACTOR *in* INSTRUMENT DESIGN

By LYNN S. BEALS, JR., Commander (Medical Corps), U.S. Navy.

Instrument dials and control knobs can be improved and made more useful by careful analysis and design of size, resistance to motion, grouping, direction of motion, numbers, letters, pointers, and scale divisions. The analysis involves psychological, medical and anthropological factors.

General

THE phrase "Humanistic Instrumentation" implies instruments for human use designed by operator-oriented engineers. This is one of the objectives of Human Engineering, which is defined as the application of psychological, medical, and anthropological principles as they relate to man-machine combinations—that is, the human factors in man-machine systems.

Unfortunately, human factors are seldom constant or independent, being inextricably mingled with machine functions and biologic factors. This prevents establishment of many rules or formulae with general applicability, and make Human Engineering, like clinical medicine, something of an art. It is based both on a philosophy and on an impressively growing body of facts. This article emphasizes the philosophy, with lesser emphasis on specific examples of the philosophy in operation.

The Problem

As machines have become more complex functionally—doing more tasks more precisely in shorter periods of time—they have become endowed with increasing numbers of indicators and instruments. As a result, some machines have become so loaded with instruments that they require skilled operators. New functions require new instruments, and when designers run out of space on a panel or console, recourse is to either miniaturization or multiple-pointer indices. Only within the last few years has there been appreciation for the fallacy of these approaches, the end-point of which is the yielding of less and less information. Adding instruments or indices to an already over-loaded instrument panel only compounds the felony.

In aviation, for example, instrument loading of the pilot had grown to such magnitude by the end of World War II that only a small portion of the population could be trained both to fly and to fight simultaneously. The requirements imposed by all-weather and supersonic flight implied additional instrumentation, which could not be tolerated in the already complex information displays of high-performance aircraft.

Re-examination of the pilot task through job analysis indicated that the chief instrumentation deficiencies lay not in design detail, lighting, or arrangement, but in that information was seldom available in an immediately usable form. This is not to say that design details are trivial, but the fundamental problem is determining what kinds of information are needed and how it can be displayed best to coincide with natural patterns of understanding. Solution to the latter problem involves investigation of sensory, motor, and intellectual capacities, and the discovery of displays and controls to which the average operator can react with greatest speed, accuracy, and convenience. These results translated into design practice achieve a "hardware" product which does not overload the psychological and physiological resources of the operator.

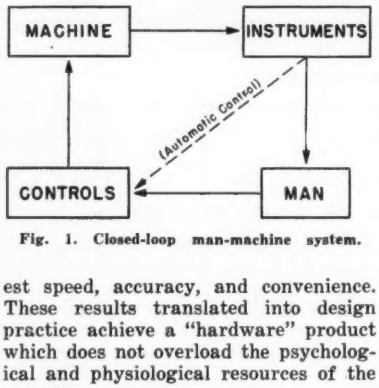

Fig. 1. Closed-loop man-machine system.

In military aviation, it has been the custom to regard the pilot as a highly mobile, reliable, and relatively low-cost computer with an almost infinite capacity to solve many complicated problems simultaneously. Increased performance of aircraft required supplying the pilot with more precise data, more scale range, and a greater quantity of total information. As a result, panels became choked with instruments and the instrument faces in turn became choked with multiple indices, until finally the accuracy of interpretation was compromised by the complexity of presentation.

Instrumentation Analysis

The initial premise in the analysis of aircraft instrumentation was that lowering the instrument load would allow more of the pilot's resources to be directed toward the military mission of his flight. The corollary of this is that in the operation of any machine, reduction in load permits using less-skilled operators.

The basic concept was that the pilot (or operator) is one of four "boxes" in a closed-loop system in which the other three boxes are the machine, the instruments, and the controls (Fig. 1).

One obvious technique for reducing operator load is *automatic control*. Part of the aircraft problem, therefore, has been to determine how much of the function previously assigned to the operator could be made automatic within the machine.

As automatic functions and controls are generally impractical in aircraft because of size and weight limitations, the main problems stem from the indicating instruments. Information provided by the instruments sometimes is not in an immediately useful form for reasons such as:

1. A number of indications must be combined, integrated, or substituted in a formula before a pilot judgment can be made.
2. A numerical indication must be compared with some independent standard in order to get a qualitative description of machine condition.
3. Most symbolic displays have little relation to past experience or inherent patterns of comprehension, and depend on purely artificial references.

Design Philosophy

The objective of correcting the deficiencies led to a general philosophy of "functional" instrument design—namely, that instruments shall:

1. Provide all data in immediately useful form without requiring pilot calculation which could be performed behind the panel.
2. Provide specific numerical information or qualitative indices where required, performing comparisons with a standard behind the panel.
3. Present graphic, pictorial, or symbolic displays in a manner that assures responses with minimum pre-indoctrination or instruction.

Note that the term "functional" is used instead of the more familiar term "standardized." This seems appropriate because "standardized" implies a fixed, permanent, and static arrangement. As machine capacities are continuously being extended by engineering advances, and as new functions are being added to existing machines, it is unrealistic to adhere blindly to routine or standard designs. The term "functional," on the other hand, implies that the instrumentation matches the extended capacities

Presented before the New Jersey Section, ISA, April 3, 1951. Subject report is cleared for publication by the Office of Naval Research.

of machines, and that new functions are integrated into the instrumentation as well as into the machine. The philosophy of design and the method of solving instrument problems can and should be standardized.

The problem is based on determining what sort of controls can be made automatic and how best to present the information required for the operator. Implicit in this determination is what the operator is required to do with, before, after, or over-and-above the automatic controls. This sort of open-ended equation in man-machine systems represents a duality of control and introduces a new set of complications to which no general solution has been found. Each new situation must be appraised separately.

Controls

The problem of control design is not as large as for the indicating instrumentation. There is, however, a definite set of general principles governing control design, with the goals of:

1. Assuring accuracy, speed, and reliability with minimum physical demands on the operator.
2. Assuring correspondence between control and indicator direction.
3. Functionally grouping controls, based on such criteria as frequency of use, importance of function, and relationship to instrument indices.

There are some accepted research results bearing on control design. These results should be examined before application to assure that the context of the research parallels the operational situation. As a step in the direction of making detail data available to professional groups, the Human Engineering Division of the Special Devices Center has prepared and distributed among the Federal agencies a "Handbook of Human Engineering Data for Design Engineers."[1] This volume can be obtained at nominal cost from the contractor—Tufts College, Medford, Mass. Another source is a volume entitled "Applied Experimental Psychology," by Morgan, Garner and Chapanis.[2] This latter volume contains material gathered during research by Johns Hopkins University Systems Research Laboratory under contract to the Special Devices Center. Channell and Tolcott[3] have indicated how human-engineering data can be put to use in equipment-design problems.

Design and Location of Controls

Many machines contain crank or winding controls for entering information into equipment. Large, coarse entries as well as finer, more precise adjustments may be required. The elements of design in this problem lie in selection of proper size, winding speed, and resistance of the cranks to assure quick and accurate machine adjustments.

Size.—Although solutions vary somewhat, depending on certain characteristics of each problem, it can be said[4] that the best radius for winding handles is 3 to 4 inches, and that the optimum winding speed is of the order of 100 to 200 rpm. The value of the speed recommendation applies only in case of fixed speed, or of a speed range less than 2:1. When speed ranges exceed 2:1, two gear ratios should be considered. In the crank problem, three possible positions might be (1) an "in" position for rapid slewing of the dials

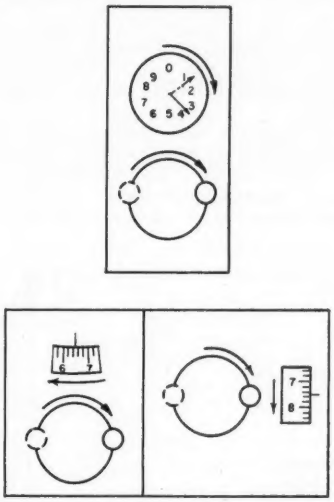

Fig. 2. Satisfactory relationships between control and indicator movement.

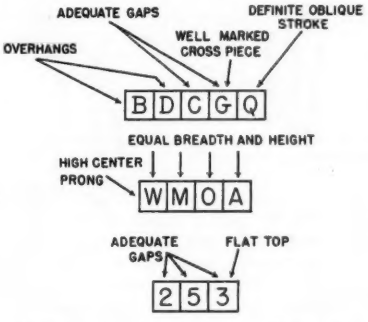

Fig. 3. Optimal designs for critical letters and numbers.

in either direction, (2) an "out" position for finer adjustment, and (3) a mid- or off position to prevent accidental change.

Resistance.—The question of frictional resistance has not been settled. Although Hick[5] states that friction has adverse effects on speed of winding if repeated operation is required, Orlansky's survey[6] suggests that some friction is desirable for smooth positioning. This apparent conflict is not serious. Sophisticated interpretation, whether by designers or by human engineers, demonstrates that recommendation for frictional resistance must reflect a compromise between smooth operation and operator fatigue.

Grouping.—Functional grouping of controls has its greatest usefulness for controls which are activated simultaneously or in rapid succession. Time and motion studies in each new design must be used to establish the optimum arrangement. Industrial studies by Mundel[7] and Barnes[8] have verified the importance of grouping controls for motion economy and of distributing controls between right and left hands. In addition to these criteria, McFarland[9] has emphasized control location determined by importance and frequency of use.

When controls are located close together, the probabilities of selection error arise—particularly under stress. If discrimination between controls depends on touch, a separation of at least six inches is desirable for controls located at arm's reach in front of the body[10]. About 12 inches is required for such discriminations to the side or rear of the body, or above shoulder height.

Color and shape coding can be employed to reduce error. Training which emphasizes certain motor skills or pattern of skills may be another technique to reduce operator errors—particularly in existing equipment which is not of the best design.

Direction of motion.—Once the nature of a control and its location have been determined, there occurs the problem of selecting in which direction it shall move. As most controls affect some indicators, the relationship between the two is described as "correspondence." Vince[11] found highest accuracy of performance when control movement is in the "expected" direction relative to the indicator. Warrick[12] stated that preference exists for control and indicator to move in the same plane and in such fashion that the part of the control nearest the indicator moves in the same direction as the indicator (Fig. 2). Warrick's indicators were only a row of lights, but many of his problems relate to controls for moving pointers on dials or for rotating dials past fixed reference marks or apertures. In these cases, clockwise control movement should provide increased indicator reading, and vice-versa.

If the dial has a moving pointer, its clockwise movement should indicate increased reading. Therefore, it is recommended that control and pointer move in the same direction.

The toggle-switch has not been afforded the dignity of research, but due to widespread experience, upward movement is expected to put it in an "on" position.

Design of Visual Indicators

An important factor in visual indicator design, regardless of function or display, relates to letters, words, and numerals. Quantitative data may be displayed on direct-reading counters or scales requiring interpolation; even a signal light usually has an identifying label. Controls also must be labeled.

Specifically, some of the research results as to legibility of letters are as follows (Fig. 3):

1. *B* & *D* need overhangs.
2. *C* & *G* should have well-marked

Continued on page 1337

"Balanced" *and* "Variable-linked" AUTOMATIC RESET

By CLIFFORD H. GEST, American Potash & Chemical Corp., Trona, Calif.*

MOST modern control systems use proportional response, whereby the valve or other controlling final element is moved an amount proportional to the deviation of the controlled variable from the desired value, or control point. For high-sensitivity control—that is, where the *proportional band*, or range of the variable through which the control mechanism is moved from one extreme to the other, is narrow—the proportional form of control is satisfactory when demand varies. A small deviation from the control point then adjusts the control mechanism sufficiently to compensate for the changed demand, and the variations in temperatures or flow are not serious. However, if a wider proportional band (lower sensitivity) must be used because of overcontrol and cycling, then changes in demand do not produce sufficient control action. This results in serious droop, or deviation from the control point, and can make proportional control valueless in many applications.

An operator can remove droop by changing the set point of the controller to correct the condition. By moving the control point, the operator moves the proportional band of the instrument. However, another change in demand makes another setting necessary, and some of the advantages of automatic control are lost by the increased personal attention required.

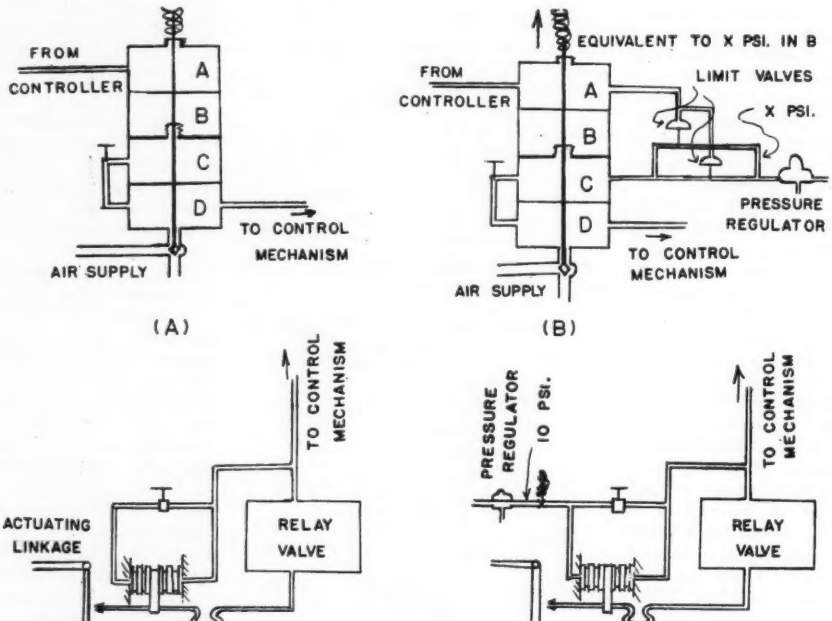

Fig. 1.—Pneumatic controllers. (A), Diaphragm-chamber and pilot-valve relay for proportional plus reset; (B), proportional plus balanced reset; (C), nozzle and flapper type relay for proportional plus reset; (D), proportional plus balanced reset.

Automatic Reset

In order to relieve the operator of the necessity for resetting his control index during periods of changing demand, the control response known as automatic reset is incorporated in many modern controllers. This device automatically moves the proportional band of the instrument to return the variable to the control point.

In one form of pneumatic controller, use is made of pneumatic relays to provide proportional plus reset action, as shown in Fig. 1 (A). Chambers A, B, C, and D are isolated from one another by diaphragms which are attached to the stem. With no pressure in B and C and no tension on the spring, pressure into A depresses the stem against the spring, thus allowing air to enter D until the pressure in D is the same as that in A. The stem then is returned to its normal position by the spring. Thus, the device acts as a one-to-one pressure relay, and control is of the proportional type.

The adjustable bleed from D to C introduces automatic reset into the control system. An upward tension equivalent to the instrument control pressure when the variable is at the control point (normally about 15 psi.) is placed on the spring. When the variable is at the control point, the pressure in A balances the upward tension in the spring and the stem is in a neutral position, holding in C and D a constant pressure of any value within the control range. As the variable is at its

*For a general article—with 17 illustrations—on the instrumentation of this huge plant, see "Measurement and Control at Trona" by the same author, *Instruments*, Dec. 1949, pages 1155-1160.—Ed.

"Balancing" the automatic reset circuit when the process variable is outside the proportional band permits reset to be used on start-ups and decreases overshoot.

"Linking" the reset to the proportional band so that reset action stops when the control limit is reached permits severe load conditions to be handled without excessive overshoot.

In a private communication to the editor, Mr. Gest asserts that "both forms of improved automatic reset have been in use at Trona since 1949 and have exceeded my expectations."

control point, a steady state of control is reached, but the control pressure in D may or may not be the same as in A. If the variable changes in value, the controller transmits a new proportional pressure to A, and the balance between A and the spring is upset. The stem then acts to adjust D to make up for the unbalance. This is proportional action. However, the correction introduced into D slowly bleeds into C and the relay becomes unbalanced again. Thus the action started by the original deviation of the controlled variable CONTINUES at a rate dependent on the deviation (expressed as a pressure difference across the bleed) and on the amount of resistance to air flow in the bleed (introduced by means of a needle valve). This action delivers varying control pressures to maintain the set value of the variable without resetting the control point manually. In effect, the proportional band of control is shifted up to fifty percent of its width. The rate at which it is shifted, or RESET RATE, is the number of times per minute the original proportional response in A is repeated and added at D. The reset rate can be adjusted by means of the needle valve; the more nearly closed the valve, the slower the reset rate.

Another type of controller uses a nozzle and flapper. In this controller, automatic reset is incorporated in the instrument itself rather than by use of a multichamber relay. As shown in Fig. 1 (C), a bellows is used to vary the relationship of nozzle and flapper. This is the left-hand bellows; the right-hand bellows is the sensitivity-reducing bellows. The relay is reverse-acting. Normally, the position of the nozzle or flapper is adjusted so that the proportional band is symmetrical about the control index, and the pressure within the bellows is half the control range (approximately 10 psi.). A steady output pressure can be obtained only when the pressures in the two bellows are equal. In other words, a steady-pressure state can be maintained only when the variable is at the control point. The pressures on both sides of the needle valve are then equal and remain so until the variable leaves the control point. When this occurs, a proportional change in the output pressure occurs, and the sensitivity-reducing bellows adjusts the nozzle to a new position. However, the changed pressure leaks through the needle valve, and the reset bellows readjusts the position to increase the original output pressure change still further. This action continues at a rate adjustable by means of the needle valve until the variable is returned to the control point (pressures in the two bellows equal) or until one of the limits of control pressure is reached. The effect is to move the proportional band fifty percent of its width up or down on the scale of the variable.

LIMITATIONS OF NORMAL RESET

Reset is valuable in the control of continuous processes and has found wide application in industry. However, a study of reset action in pneumatic controllers shows that this action continues until the variable returns to the control point. This ordinarily leads to overcorrection for sharp changes in demand on the control system ("reset overshoot"). If the control pressure is at neither extreme, the return to the control point is started within the proportional band. The proportional response then changes the control pressure in opposition to the continuous reset change, and the overshoot either is not serious or can be removed by use of rate action. However, if the variable is outside the proportional band for an appreciable time, or off the control point for a long time, the pressure in the reset bellows (chamber C in Fig. 1 A) reaches one extreme or the other, and the proportional band is displaced 50 percent of its width in a direction opposite to the deviation of the variable. When this occurs, no change in control pressure results from approach of the variable to the control point until it reaches the control point, and the variable arrives at the control point with the control mechanism in one extreme or the other. This condition, termed "reset lock-up" results in a large overshoot before the process steadies out: The slower the rate of reset, the greater the length of time required for the reset bellows or relay to come to a balance with the rest of the system.

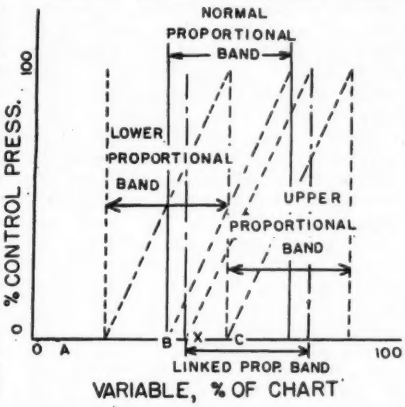

Fig. 2.—Graph showing how the proportional band is shifted by reset action.

The overshoot caused by reset normally is not serious enough to be objectionable in a properly-designed control system for a continuous process. In a discontinuous or batch process, however, it often results in over-shoots which render use of reset impossible.

Fig. 2 shows what takes place in normal reset. The control pressure (0-100 percent of the control range) is shown as a function of the measured value of the variable. The "normal proportional band" is the one obtained without reset. Point C is the control point. The upper and lower proportional bands refer to the limits to which the reset function can shift the proportional band. With the proportional band in its upper position (as it would be when the variable has been below the control point—as at "A"—for a considerable length of time) no control action can be expected from a rising variable until the valve reaches C, the lower limit of the displaced proportional band. This means that no control action begins until the control point is reached. This causes overshoot.

"BALANCED" RESET

Study of the problem of a start-up, as in a batch process, indicates that some means should be developed whereby the control system enters the original proportional band with the reset system balanced and prepared to act in its normal manner, rather than locked up. Normally, a correctly-tuned system, with reset, particularly if it includes rate action, is returned to the control point from any point within its proportional band without serious overshoot. For the solution of most start-up problems, therefore, it is sufficient to have the proportional band in its normal position, so that as the variable approaches the control point, it enters the proportional band. Proportional control then is exercised with reset starting from scratch, so to speak. The position of the proportional band is determined by the pressure within the reset bellows, or chamber C of the relay (Fig. 1A). Therefore, if this pressure is held at its normal value whenever the variable enters the original proportional band, normal reset control is obtained on a start-up. Rate action can be used to minimize overshoot.

Figs. 1(B) and 1(D) represent methods of attaining the desired balance in the bellows and nozzle types of reset systems. In Fig. 1(B), one of the two pneumatic snap-action limit valves opens at an air pressure corresponding to the upper limit of control. The other opens at a pressure corresponding to the lower limit of control. Pressure in A is assumed to be proportional to deviation. The control range usually is 5-25 psi. When the variable reaches either limit of the normal proportional band,

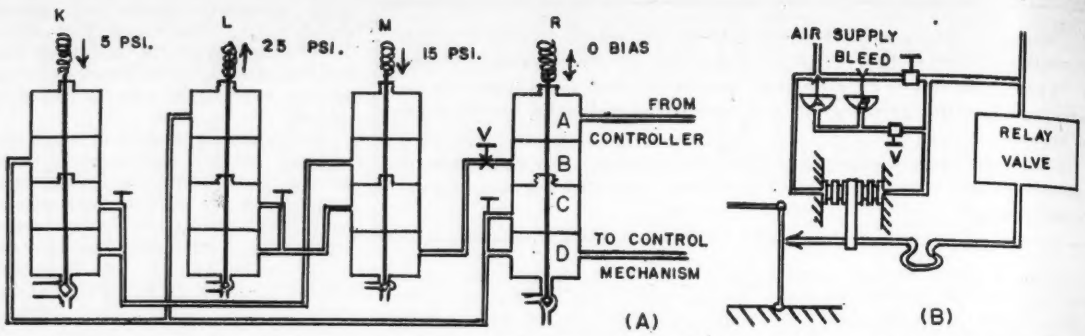

Fig. 3.—Methods for obtaining variable-linked reset action for (A) pilot-valve type controller, and (B) nozzle and baffle controller.

therefore, reset Chamber C (Fig. 2), is returned to X psi. and the danger of lock-up is removed. Note that no change in control action results from this balancing, because proportional action produces full control action at this point. This applies also to the nozzle and flapper type of reset controller.

When the variable enters the proportional band, the limit valve which was open is now closed, and normal reset action starts to bring the variable to the control point. If the approach is too fast, rate action can be used over half the proportional band. This also applies to nozzle and relay type control.

In the nozzle and relay type, a proportional source of air pressure is not as available as in the relay type of reset. However, limit switches which are set at the upper and lower limits of the proportional band can be used. These switches actuate the solenoid valve to deliver 10 psi., or normal pressure, to the reset bellows whenever the variable is outside the proportional band.

In another type of pneumatic reset device, the reset bellows is filled with a liquid. The balancing pressure can be introduced around the reset bellows to produce the same effects. Modifications can be introduced easily into electrical systems to achieve the same effect.

For most batch or discontinuous processes, the "balanced start" described is sufficient to remove objections to the use of reset. Although reset begins to function immediately, the rate of proportional band shift is less than the rate of increase of the variable, and control action begins. Rate action then can be used to bring the variable smoothly to its proper value.

"Variable-linked" Reset

The system of "balanced reset" operates only when the approach to the control point is made from a value outside the normal proportional band. During prolonged overload, the control system may reach the limit of its abilities with the variable still within the normal proportional band. Under these conditions, the conventional reset systems continue to move the proportional band to one limit or the other. This action introduces a dead spot in the controller, which causes overshoot when the overload is corrected. Referring to Fig. 2, an overload may have held the variable to a value of X even though the control system was at its limit. Reset acts to move the lower limit of proportional band from B past X to C. If the overload is removed and the variable approaches the control point, C, no control action takes place until C is reached. Thus, a dead spot extending from X to C is introduced by reset action. Had the proportional-band shift been stopped when the lower limit reached X, the control system would still be at its limit (the variable at the edge of the proportional band), but the rise in the variable could be recognized immediately—that is, the dead spot would be eliminated, and corrective action initiated. The problem, then, is how to stop the shift of the proportional band when one limit or the other reaches the value of the variable. This can be accomplished by additional equipment within the controller. When this is done, the "balanced reset" is no longer required on start-up because one edge of the proportional band follows the variable within the limits of twice the normal proportional band, and remains at the limit until the variable again enters the band. In other words, the position of proportional band is "linked" to the value of the variable.

The Improvements

One method of limiting the proportional band shift is to stop the reset action when the control limit is reached, and thus prevent it from generating the dead space. A positive lock, however, results in a new dead space if the variable continues to deviate from the control point. The systems to be described, which use "variable-linked" reset, keep any dead spot from developing because they not only stop travel of the proportional band when its edge reaches the value of the variable, but displace it against normal reset if the variable deviates still further from the control point. When control is regained, as evidenced by movement of the variable toward the control point, the control system becomes a normal reset controller.

In Fig. 3 (A), R is the original relay with reset. Relays K and L act as pressure controllers when the output from R exceeds the control limits (5-25 psi.). The output pressures from K and L are used to modify the output of relay M, and hence the pressure in chamber B of relay R. Thus the pressure delivered by R always is held within the control limits, and the control system always is prepared to act. Valve V controls the rate at which the edge of the proportional band is allowed to follow the variable. This provides for entry into the proportional band.

Fig. 3(B) represents the application of "variable-linked" reset to the nozzle and baffle type controller. Regulators A and B adjust the pressure within the reset bellows whenever the controller output exceeds the control limits of air pressure for the system (usually about 2-16 psi.). Leakage through the upper reset valve is exhausted either through B or the through the relay valve, depending on the differential across it. Although two regulators (A and B) are shown, they can be replaced with a pressure-actuated three-way valve which has a dead spot covering the control range. Lower valve V controls rate of return of the proportional band to normal reset position.

Conclusion

The developments are the result of difficulties experienced with discontinuous processes in bulk chemical manufacture, primarily due to periodic plant or equipment washouts. Reset response is needed in many of these processes, but cannot be used in its simpler form because of serious overshooting. As local opinion is that "it isn't truly automatic if it has to be started manually," the "balanced reset" has been developed and applied to such problems, and has proved to combine the advantages of proportional start-up with automatic-reset operation.

The "variable-linked" reset is a more general development to include sudden cut-off after periods of mild overload, or sudden heavy loads supplied after prolonged periods of underload. It handles start-ups also. For start-ups which are controlled with difficulty, the fact that this system is able to displace the proportional band 50 percent of its width makes it still more valuable than balanced reset. This is because control action can be started 100 percent of the bandwidth below the control point, and there is no loss of sensitivity or reset response after the start-up is completed.

Process Instrumentation *in* The Nuclear Field

By V. L. PARSEGIAN,

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PROCESSES and techniques used by the nuclear industry are quite varied. For example, the operations involving mining and purification of minerals, and fabrication of uranium, use techniques that are common to a hundred other metals industries, the principal difference being the extremely high purity to which the uranium must be processed. But when the uranium must be reprocessed after exposure in the atomic reactor, say to remove the plutonium or fission products, the material is so radioactive that an operator would not dare touch the process vessels with the proverbial "10-ft. pole."

The vessels, pipes, and equipment containing radioactive liquids must be confined to well-shielded cells which are surrounded by thick walls of concrete. This area becomes inaccessible to the plant operator or maintenance man except under very special conditions. Equipment or instrument parts that come in direct contact with the liquids are difficult to decontaminate; when an instrument that has had contact with these fluids fails, it usually must be replaced by remote manipulation. As the instrument panels must be mounted in instrument rooms that are free of dangerous radiation intensities, process instruments must be designed with the detector element in "no man's land," the meter on the instrument panel, and the connection of the two through a maze of concrete.

System Needed

Measuring systems are needed which permit telemetering of intelligence between radive and non-radive areas, without introducing gaps in the shielding system through which radioactive vapors can pass to the safe, or non-radive, areas. Mechanical systems are the least desirable in this respect; pneumatic systems are a popular second choice, and electrical systems offer unique but as yet not fully explored advantages. Similar considerations hold for manipulating devices.

The process instruments measure the ordinary variables, such as temperature, liquid flow rate, liquid level, pressure, and composition, plus radiation as a new process variable.

Instrument Improvements Needed

The most significant instrument improvements are needed in connection with *detector elements* for measuring these variables. One can tolerate complexity at the instrument panel if the detector element is correspondingly simple, dependable, assured of long life, easy to replace without stopping of process flow, free of contact with the radioactive liquid, easy to standardize by remote devices, resistant to corrosive fumes, sensitive, with no moving parts, and "packaged" and rugged—in approximately this order of decreasing importance.

For *temperature measurement* there is needed a simple disconnect device to permit easy replacement of thermocouples or resistance-thermometer elements by remote manipulation. Such a disconnect device should withstand corrosive atmospheres for many years without developing "battery" effects or variable resistance change.

Liquid flow-rate measurements present serious problems because conventional instruments require that the radioactive liquids pass through constrictions of the meter, and make use of moving parts. Replacement of these units becomes particularly difficult and dangerous, and requires closing down of process operations.

Liquid level can be determined without use of moving parts inside the fluids by making use of dielectric and other properties of the liquid as measured by a pickup placed outside the vessel or special cell. Commercial instruments are needed having ranges varying from a few inches to many feet; a range of two feet is quite common. Sensitivity of ±1 percent of the range, and an accuracy of ±5 percent, are satisfactory for most applications.

Pressure measurements are useful for measuring flow rate and liquid level, and sometimes for solution composition when accompanied by changes in density. Sensitivity requirements vary, sometimes requiring detection of changes of one-half inch of water at a total pressure of 50 ft. of water.

Fluid composition measurements are as useful in nuclear as in other industries, but the difficulties are more serious.

Remote sampling techniques require development of a good pump for circulating small streams of solution to sampling gallery.

The presence of nuclear radiation in solutions offers both a hazard and a valuable process variable. Unfortunately, not enough use is made of this variable, largely because good radiation-measuring instruments which are suited to plant conditions are not yet available. Detectors of the total-ionization, direct-current type are likely to be most useful. These detectors should be small enough to attach to pipes, and they should be designed to measure gamma radiation intensity from many roentgens to background, if possible. There is needed also a high-pressure gas chamber, or detectors of the solid- or liquid-dielectric type. These probably should be designed with a preamplifier.

The new nuclear industry poses problems of measurement which require the development of new detection techniques and new concepts of instrument performance and dependability.

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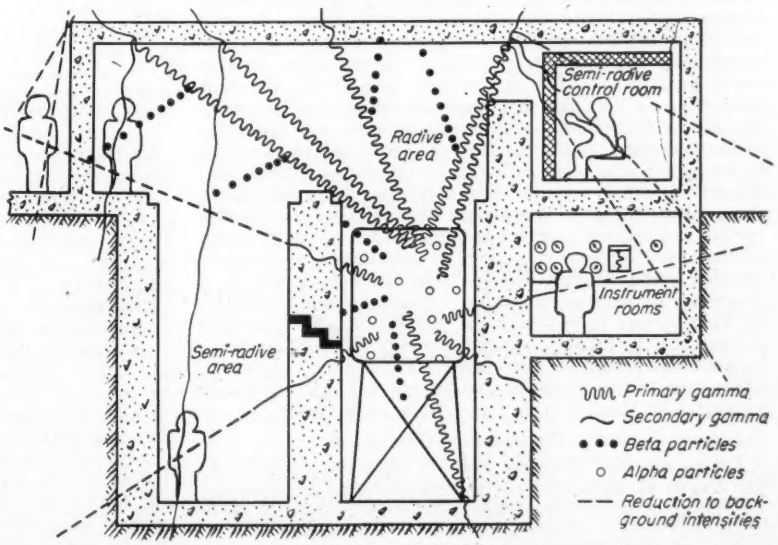

Distribution of radiation in a radiochemical processing plant.

Presented before the Regional Conference of the N. Y. Section, ISA, January 26, 1951.

Application *of* Continuous Infrared Analyzers

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One of the leading instruments in the analyzer age, which already has begun, will be the continuous infrared analyzer. Already in use on many industrial processes, this instrument will be the heart of many completely automatic plants of the future. This article discusses principles, applications, and existing problems.

DURING the last decade the analysis of mixtures of organic compounds by means of the infrared spectrometer has become well established. The process industries have exhibited marked interest in the application of continuous infrared analyzers to plant streams to such an extent that the availability of analyzers of various designs is rapidly increasing. The purpose of this article is to discuss the theory of infrared spectroscopy as utilized by the spectrometer and to show how a more simple and rugged instrument has been developed for the industrial plant. The various types of non-dispersive infrared analyzers will be discussed, including how an infrared analyzer is set up and calibrated for application to a multicomponent system. Some of the considerations which must be analyzed when one is confronted with the task of applying an infrared analyzer to a given problem will be discussed.

Infrared Radiation

Let us first consider fundamentals. You have all heard of X-rays, cosmic rays, ultraviolet rays, and you have all seen a rainbow, which is the splitting up of visible light into its various colors. All of these rays have several things in common. They all have electrical and magnetic components and travel with the speed of light. They differ from each other in the frequency of vibration or wavelength. Placed in their proper wavelength order they form what is known as the electromagnetic spectrum. When we speak of infrared radiation we are referring to that part of the electromagnetic spectrum which lies just beyond the red end of the visible spectrum. Wavelengths in this region are usually measured in microns, a micron being one-millionth of a meter. The infrared region extends to about 3000 microns, but for all present-day practical purposes the region is limited to about 15 microns, i.e. from the visible spectrum ending at 0.75 micron to 15 microns. In laboratory circles this is referred to as the "Analytical Region" because most of the information pertaining to the analysis of functional groups of atoms is found in this region. An important point to remember about this region of the spectrum is that sources of this infrared radiation, whether globar (silicon-carbide rod), nernst glower, or a nichrome filament when heated to approximately 1100 C., all have a peak radiation in the vicinity of 1-2 microns, as shown in Fig. 1. Note that the energy rapidly decreases as one moves toward the longer wavelengths. Therefore, absorption bands found beyond 10 microns are not nearly as useful as those found in the 2-4 micron region.

Absorption Bands

Let us consider what we mean by absorption bands. As you know, all molecules not at absolute zero are made up of groups of atoms which are constantly oscillating about their positions of equilibrium. These frequencies of vibration are of the same order of magnitude as those of infrared radiation, so that if a molecule is irradiated by a beam of infrared, the atoms vibrate with respect to each other with certain preferential, or resonant, frequencies. The graph which is obtained by plotting the percentage of radiation transmitted as a function of wavelength then can be interpreted in terms of intramolecular motion. The infrared spectrophotometer plots these areas of vibration or absorption bands and, by proper study, one can obtain information about intermolecular structure. Even more important, the analyst can identify molecules and measure their presence quantitatively.

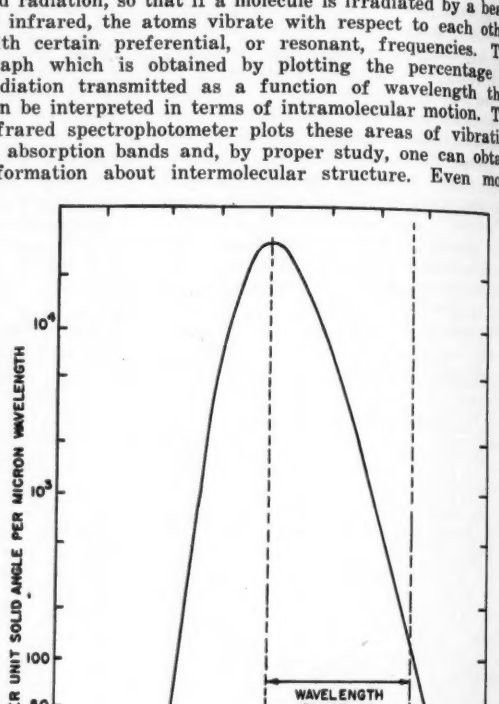

Fig. 1. Wavelengths of radiation from a 1-cm. square black-body source at 1100 deg. C.

When the infrared spectrophotometer is used in the laboratory to analyze a sample, the light or energy is broken up into its various wavelengths by means of a prism or grating. The resultant energy transmitted by the sample being analyzed is measured step by step. When one considers the high resolution obtainable in current-day spectrometers, together with the low energy of the source used, it is immediately obvious that the resultant energy or signal obtained from any small increment of wavelength is extremely small and, therefore, its measurement necessitates high amplification. Therefore, instruments which function reliably in laboratories are hardly rugged enough for installation in plant locations.

Rather than attempt to construct spectrometers suitable for continuous operation in plant environment, instrument makers have utilized a principle which is commonly used in the visible range of the spectrum and which simplifies the instrumental requirements. Instead of separating the

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energy into its various wavelengths and measuring each consecutively, regions in the spectrum are isolated by suitable filters. Filters consist of materials which transmit restricted regions of the spectrum. Compared with the spectrometer, the instrument now measures broader bands, and many simultaneously, so that even minute differences of individual bands when integrated yield a considerably larger signal. Less amplification is required, and the signal-to-noise ratio is more favorable than in the spectrometer.

Non-dispersive Analyzers

Let us now consider the various types of the non-dispersive instrument which can operate outside the laboratory. They can be divided into two main groups. One group utilizes chopped radiation which produces a pulsing signal on a selective detector; the other uses a steady beam of radiation falling on a non-selective detector. A selective detector is one that absorbs energy of a specific region, whereas a non-selective detector absorbs all energy.

The chopped-beam instruments were initially developed in Germany and are commonly called Luft Analyzers. The instrument utilizing the selective detector is called the "positive" type; the one utilizing the non-selective detector

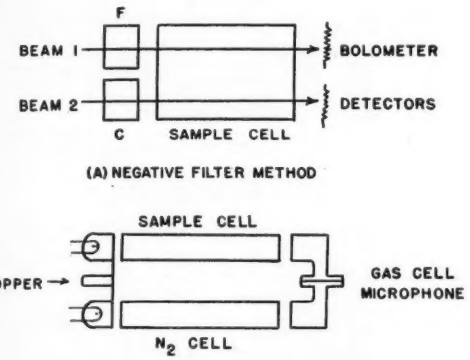


Fig. 2. General methods of gas analysis.

is termed the "negative" type. Fig. 2 illustrates the optical diagrams of the two types.

In the positive type the radiant energy from the source is alternately interrupted, or chopped, by the motor-driven cam. A single source may be used with two mirrors rather than two sources as illustrated. The alternating pulses pass through the cells in each beam, the sensitizing cell, S, and the sample cell. The resultant is an alternating signal with a frequency equal to the speed of the chopping cam. The detector used consists of a gas microphone which is essentially a two-compartment gas cell separated by a thin metallic membrane which forms one side of a capacitor. The cell is filled with the gas to be measured. If energy of the proper wavelength (i.e., wavelengths where absorption bands are found) falls on the detector, the gas expands and thereby separates the sides of the capacitor, changing its capacity. Energy of other wavelengths causes no change in capacity. Therefore, as the concentration of the measured component changes in the sample cell, it permits varying amounts of this characteristic energy to reach the detector. The capacity changes as the concentration. The signal then is amplified and recorded.

In the steady-state-type instrument, commonly called the negative-filter type, the energy is divided into two paths, both of which pass through the sample cell. Only one passes through a filter cell; the other passes through a compensator cell. The value of this cell will be discussed later. The energy then falls on two non-selective infrared detectors, which make up opposite arms of a bridge circuit. The bridge is continually maintained in balance by the slide wire of the recorder. The filter cell F (Fig. 2) is filled with 100 percent of the component to be measured, while the compensator cell C is filled with nitrogen or a mixture of gases present in the sample, but whose analysis is not desired. When the concentration of the component being measured changes in the sample cell, it does not affect the intensity of the upper beam because the high concentration in the filter cell effectively removes all the energy which this component absorbs. However, the lower beam is affected by the change in concentration of the measured component, and results in an unbalance of the bolometer bridge. As other infrared-absorbing components change in concentration in the sample, they cause an equal change in both beams so that the system is not unbalanced and no change is recorded, provided that the bands do not overlap with the bands of the measured gas. However, most gas systems do have components with overlapping absorption bands. It is the elimination of this effect which gives the instrument engineer the most trouble. When the other components do have common absorption bands with the measured component, another cell, called the "interference cell," is used. This cell is common to both beams. The interference cell is filled with higher concentrations of the interfering components than are ever anticipated in the sample stream. Thus the instrument is made insensitive to energy changes in the regions of common absorption.

The fundamental difference between the two systems is that the former, the positive-type instrument, measures only energy that is absorbed by the component being measured. In the latter system, the negative-filter instrument, the infrared detectors measure all the energy which gets through the system. It is a case of measuring a large signal against no signal in one, and a small signal against a large background signal in the other.

Multi-component System

Let us now consider the application of an instrument of this type for the analysis of a multi-component system where all gases have common absorption bands. Engineers in the petroleum and chemical industries have long recognized the need for the continuous analysis of ethylene in the presence of ethane and methane. A solution to this problem has been found and has proven itself during the last two years by the satisfactory operation of a continuous analyzer for this analysis. The following description of how the instrument is set up for this analysis gives an idea of the difficulties that had to be overcome. It is evident from an examination of the absorption spectrum of ethylene, methane, and ethane (Fig. 3) that any non-dispersive instrument that is sensitive to one of the gases, also is sensitive to all three, with the most serious interference existing between the ethylene and ethane. The only spectral region in which ethylene absorbs completely free from ethane interference is in the 5- to 6-micron region. The broad series of bands between 9 and 12 microns in the ethylene spectrum is partly overlapped by ethane. The usual method of desensitizing a gas analyzer to an interfering gas is to place that gas at a pressure of one atmosphere in the interference cell. This method is satisfactory as far as the methane interference is concerned because the only spectral overlap is in the 3- to 4-micron region, and methane absorbs much less strongly in this region than either ethylene or ethane. The ethane interference is so severe, however, that an excessively long interference cell would be required to remove it by this method.

As the sensitivity to ethylene is achieved by placing ethylene in the filter cell so that only one beam of the radiation passes through it, then any ethylene in the other beam (the compensator cell) will reduce this sensitivity; if the concentration is made great enough, it can eliminate it altogether. By the addition of ethane to the compensator cell, the sensitivity of the instrument changes in concentrations of ethane (due to its common absorption with ethylene) and can be reduced and eliminated completely if the exactly correct concentration is used. This reduces the sensitivity to ethylene, but not seriously (Fig. 4). The analyzer is finally set up for this problem with 100 percent ethylene in the filter cell, and 100 percent methane in the interference cell, and approximately 200 m.m. of ethane

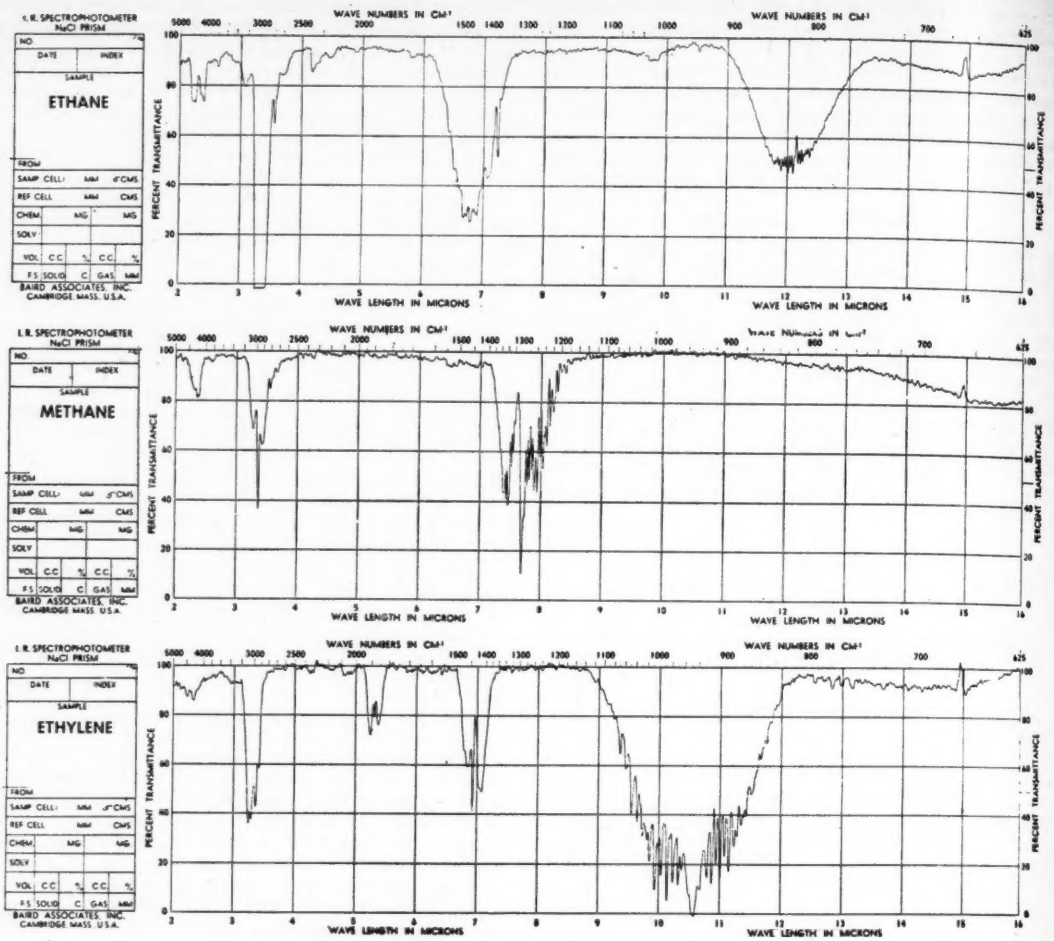


Fig. 3. Absorption spectra of ethane, methane, and ethylene.

in the compensator cell. Several attempts have been made to work out mathematically a method for predicting exactly what concentration should be placed in each cell in order to obtain a desired analysis. For the most part the practical solution has been to cut and try in the analyzer at the time of final calibration, with calibrated gas samples, so that the interference caused by the background gases is reduced to a minimum. Cases have been observed where a study of superimposed absorption spectrograms of gas mixtures show no differences, yet when the same mixtures are compared in a non-dispersive analyzer they exhibit measurable differences. This is due to the integration of many small differences in individual bands by the observation of the entire spectrum at the same time. Fig. 4 illustrates a typical infrared continuous analyzer. The assembly consists of the analyzer (enclosed in an explosion-proof housing), an electronic voltage regulator, and a conventional potentiometer recorder with a high-gain amplifier. The analyzer unit usually is located remotely from the recorder and regulator assembly, in some cases as far as 1000 feet.

Application Factors

The next consideration is the specific application data which must be considered when one has made a decision to apply an infrared analyzer to a plant stream. These factors are of considerable importance.

A. Basic Requirements

For the gas analyzer to measure the concentration of a given component in a gas stream, it is essential that the component absorbs energy at characteristic wavelengths in the infrared. If this property is true of a component, and if the component changes in concentration in a mixture, then there will be a corresponding change in the total energy remaining in an infrared beam after passing through the mixture. The instrument measures these energy changes, which are a measure of gas concentration.

Because of the possible presence of compounds with overlapping absorption bands, a knowledge of the concentrations of all the components of the gas system is essential for optimum use of this analyzer. A thorough chemical analysis is therefore desirable before an analyzer is selected for a definite application.

B. Sample Gas Specifications

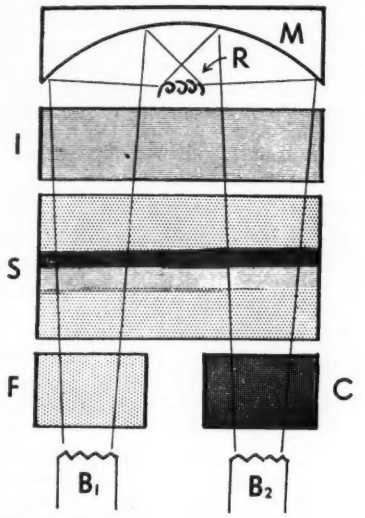
1. *Suspended Solids.* As the gas analyzer is an optical instrument, it is necessary that all gases passing through the sample cell, whether for analysis or standardization, be supplied in a clean state. Suspended solids, such as dust encountered in flue gas, would build up on the cell windows and eventually cause a reduction in the amount of infrared energy passing through the sample cell. It is recommended that a suitable dust trap or filter be placed in the sample line before it enters the analyzer. Glass wool, cotton waste, or fused silica have been found suitable for most dust conditions.

2. *Pressure.* The absorption of the infrared beam is a measure of the total number of absorbing molecules in the gas cell. In order to measure the ratio of absorbing to the total of both absorbing and non-absorbing molecules, it is necessary to maintain the same number of molecules in the cell at all times. The number of molecules in the cell will be constant only if the pressure and temperature

are constant. For most conditions, maximum allowable pressure change in the sample line at the analyzer is of the order of 2 or 3 inches of water.

3. *Temperature.* The sample cell of the gas analyzer usually is maintained by suitable heat control at a temperature of 150 F. However, sample gases with temperature as high as 200 F. may be safely admitted to the analyzer. Use of gases at higher temperature is not recommended because a reduction in gas temperature will probably result in the sample liquifying or subliming on the cell walls. Gases at room temperature or lower can be used, provided that there is no danger of reaching the dew point of the gas streams, and thereby causing condensation of liquids on the cell windows.

4. *Rate of Flow of Sample Gas.* The rate of flow of the gases entering the sample cell may vary, depending on the desired time of response of the instrument. The faster the flow rate, the sooner the concentration is changed in the sample cell. For normal operation, a flow rate of 1 to 2 liters per minute is satisfactory. The volume of the sample cell is approximately ⅓ liter.



M — Spherical Mirror
R — Infrared Radiator
I — Interference Cell
S — Sample Cell
F — Filter Cell
C — Compensator Cell
B_1, B_2 — Bolometer Elements

Fig. 4. Schematic of typical continuous infrared analyzer.

5. *Water Vapor.* If rock-salt optics are used, serious damage results from the formation of condensate on the windows. The sample gas therefore should not usually have a dew-point over 90-100 F. Instruments using calcium-fluoride or silver-chloride windows are not permanently affected by water condensate, although calibration will be off as long as the moisture remains on the windows.

6. *Corrosive Gases.* As most types of instruments are available in stainless steel, this is not a critical problem.

7. *Site.* It is often desirable to locate the analyzer unit on the process equipment, either in the conventional cabinet-type housing, or in an explosion-proof housing. When this is done, the recorder and associated equipment are located in the control house in some remote location. The standard 19-in. panel mounting will accommodate all of these components; if instrument panel space is at a premium, it is possible to locate the voltage regulator at the rear of the panelboard.

8. *Calibration.* Calibration may be made in one of three ways: (a) all calibration work done at the manufacturer's plant, (b) all work done at the installation site, or (c) preliminary calibration at the manufacturer's plant, and a final calibration at the installation site. Of these three plans the second and third are preferable to the first. If calibration work is to be carried out at manufacturer's plant, it is usually desirable that analyzed samples of the plant stream be furnished. In the simpler cases, where the plant stream consists of inert gases with one infrared-absorbing component to be measured, the calibration can be accomplished easily. In the more complicated case, where several infrared-absorbing components are present in the sample stream, it is desirable that the instrument be installed and samples taken from the exit stream and analyzed by other means after recorder deflection is noted.

9. *Shut-down Precautions.* In installations where the instrument is in continuous operation no shut-down precautions are necessary. In discontinuous operation where the unit is shut down for any reason, and the analyzer is not operating, precautions must be taken. It is necessary to prevent the accumulation of moisture inside the sample lines during this shut-down. This is especially important where rock-salt optics are used. One method of preventing the accumulation of moisture is to bleed dry nitrogen or dry air slowly through the analyzer sample lines.

The Present and the Future

Let us now consider the present-day applications of Infrared Analyzers and the ultimate scope of this equipment. A list of a number of applications which have been field tested and proven satisfactory in all respects includes:

n-Butane in methane, ethane, propane, iso-butane, CO, CO_2
Methane in natural and manufactured gas blends
Methane in annealing furnace atmosphere
Carbon dioxide in expired air
Acetylene in 14-component mixture
Methane in 14-component mixture
Carbon dioxide in 7-component mixture
Hydrogen cyanide in 8-component mixture
Ammonia in 7-component mixture
Monovinyl acetylene in 11-component mixture
Acetylene in hydrogen cyanide
Hydrogen cyanide in acetylene
Ethyl acetate in toluene/air mixture (lel)
Acetone in air (lel)

These represent only some of the problems and are by no means a full and inclusive list. Some time ago our organization made an extensive survey of the process industries to determine just where instruments of this type were to be used. The survey indicated that the application of this type instrument has not even scratched the surface of potential use. In years to come it is expected that thousands of these instruments will be used to analyze control-process streams.

Engineers in a number of laboratories, including the Esso Standard Oil Company, DuPont, Ethyl Corporation, and Gulf, have done much to widen the field of application of this equipment. However, we are confronted daily with analytical problems where a plant desires to measure a component in a multi-component stream. When questioned regarding the accuracy and sensitivity of the instrument to the component, the instrument manufacturer can only state that he thinks it will do so and so. Sometimes there is no actual data to back up his belief. Even though one obtains complete infrared spectrograms of all the components in a system, it still is not possible to predict accurately the result of performance of the instrument on a gas stream. Of course, we can predict with fair accuracy the sensitivity of an instrument to a gas having characteristic absorption bands completely separated from any of the background gases. However, this is the exception rather than the rule; for the most part superpositioning one infrared spectrogram on another does not answer all questions. It has been found that gas blends which yield practically identical absorption spectrograms on the spectrophotometer give considerably different results when viewed by the non-dispersive type analyzer. A 1-percent change in concentration of a single component in a gas system may cause deflections due to absorption bands too weak to be detected individually by the spectrophotometer. When absorption bands are integrated by the non-dispersive type analyzer, they

Continued on page 1340

INSTRUMENT ELECTRONICS

Signal sources and types of signals used in instrument electronic circuits are discussed, including some common transducers. Composition of nonsinoidal waveforms and the action of simple *R-C* and *R-L* circuits are described. Differentiation, integration, and coupling are discussed in detail.

By
MILTON H. ARONSON
Managing Editor
Instruments

IV. SIGNALS AND SIMPLE CIRCUITS

Signal Sources

MANY electronic instruments are designed to detect and to measure a physical condition such as temperature, pressure, mechanical strain, chemical composition, or physical dimension. Devices that convert the physical condition into an electric signal are called primary, or sensitive, elements. Primary elements often are called *transducers*. The term "transducer" is applied to devices which change the form of energy. For example, a piezoelectric crystal is a device which converts pressures into electric signals, or vice versa; a thermocouple converts temperatures into electric signals; a photoelectric cell converts light into electric signals.

The term "signal" refers to any variation of an electric voltage, current, or frequency which is used to convey the desired information about the physical condition. The function of the primary element is to produce a voltage, current, or frequency which depends on the physical condition.

There are hundreds of ingenious devices which change a physical condition into an electric signal. Although the subject is interesting, it is too extensive to be considered in detail here. However, a few primary elements are described briefly, mainly to indicate the type of input signal received by instruments.

Primary Elements for Pressure

Some devices change resistance when compressed or extended. These devices can be used as pressure-sensitive primary elements directly. For example, if a current (*I*) is sent through such an element, there is a change in *IR* voltage each time the element changes resistance (*R*). This voltage change is the signal. The *carbon pile* is such a pressure-sensitive element. The *strain gage* also is a primary element which changes resistance when extended or compressed.

Most *pressure-sensitive* primary elements operate by causing the displacement of a diaphragm, Bourdon tube, bellows, etc. The displacement then effects a change in resistance, capacitance, or inductance of an electric circuit. For example, the displacement of a thin vane between two coils can change the resonant frequency of the coils, or the displacement of a core in a differential transformer can change the output of the transformer.

Most measurements of *flow* are made by measuring the differential pressure between two points in the flowing stream. Thus most flow measurements are essentially pressure measurements.

Primary Elements for Temperature

Among the most common temperature-sensitive effects used to produce an electric signal are resistivity and thermoelectricity. The electrical resistance of platinum, nickel, many semiconductors, and other materials changes linearly with temperature. Such devices can be used as primary elements which give an electric signal output for changes in temperature.

The *thermoelectric* principle is used widely in industrial instrumentation. The thermoelectric effect results from the fact that when any two dissimilar metals are brought into contact, a potential is developed at the interface. As this potential depends on the temperature of the interface, the phenomenon lends itself directly to temperature measurement. Other temperature-sensitive effects used in primary elements include expansion, vapor pressure, magnetic susceptibility, and others. At higher temperatures the radiation emanating from the hot body can be used as an indication of temperature.

Primary Elements for Counting

Many instruments are designed to count. Some indicate the total count of a manufactured product. Others indicate the number of counts per second of a radioactive source or of an electric signal (frequency). A common primary element for counting circuits is the photoelectric cell, which produces an electric signal whenever light falls on a sensitive electron-emitting surface. The signal output of the primary element of a counting circuit usually is a short pulse which occurs only when the sensitive element is energized.

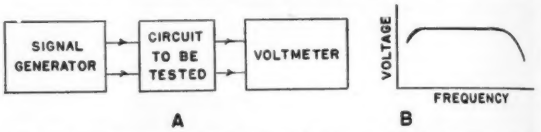


Fig. 4-1. Frequency response of a circuit. A, block diagram of circuit for test; B, frequency-response curve.

Signal Types

The primary element of an instrument produces the signal input to the instrument. The signal input can be either (1) a sine wave which changes in frequency or amplitude, (2) a nonsinoidal wave which changes in frequency or amplitude, or (3) a transient (pulse-type) signal which occurs only when the physical condition changes.

The *radar* is an instrument which measures the *time* between transient pulses to indicate the distance between the pulse transmitter and the target. The transmitter transmits a short pulse of r-f. energy which travels to the target, is reflected from the target, and returns to a receiver located at the transmitter. As the radio pulse travels at a known speed (the speed of light), the time between the transmission of the pulse and the reception of the echo is a measure of the distance to the target. The radar uses many circuits encountered in electronic instruments, including amplifiers, oscillators, pulse shapers, differentiators, integrators, and oscilloscope indicators. Hence the radar will be described after less-complicated instruments such as the oscilloscope are discussed.

Sinoidal Waves

The sine wave is a basic wave and is used in many different ways. The carrier wave which transmits radio sig-

ANSWERS TO QUIZ III

3-1. (c)	3-7. (b)	3-13. (a)	3-19. (a)	3-25. (a)
3-2. (a)	3-8. (a)	3-14. (c)	3-20. (c)	3-26. (d)
3-3. (a)	3-9. (a)	3-15. (c)	3-21. (c)	3-27. (b)
3-4. (d)	3-10. (b)	3-16. (b)	3-22. (b)	3-28. (c)
3-5. (d)	3-11. (c)	3-17. (b)	3-23. (b)	3-29. (d)
3-6. (c)	3-12. (b)	3-18. (d)	3-24. (d)	3-30. (c)

Test items for—IV Signals and Simple Circuits—page 1304.

nals is a sine wave of radio frequency. Most signal generators produce pure sine waves.

One of the most common uses of sine waves in instrument work is to check the frequency response of a circuit. As shown in Fig. 4-1, a sine wave of constant voltage is fed into the circuit to be checked. The output voltage of the circuit is measured and plotted for several different frequencies, and a curve is drawn of amplitude versus frequency (Fig. 4-1,B). This *frequency-response curve* indicates over what range of frequency the circuit operates.

Nonsinoidal Waves

Pure sine waves are basic waveshapes. Many instruments use pure sine waves. However, many other instruments use nonsinoidal waves and transient waveforms. For example, the output signal of many primary elements, such as strain gages and pressure detectors, are transient signals. *All signals, including nonsinoidal waves and transient signals, are composed of pure sine waves of different frequencies and amplitudes.* Thus any circuit can be analyzed, and the response of the circuit to any signal can be analyzed, in terms of the response of the circuit to sinoidal waveshapes.

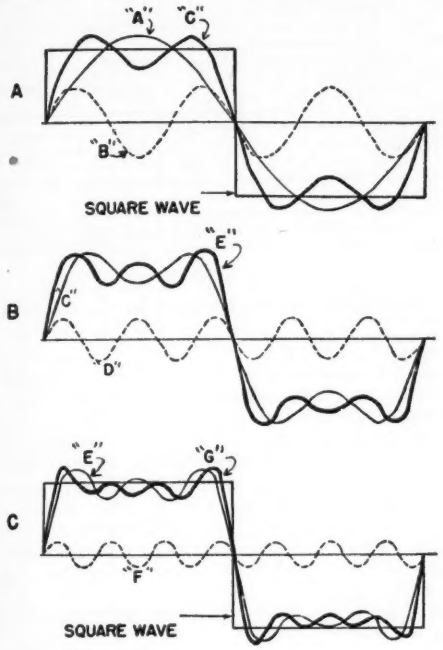


Fig. 4-2. Composition of a square wave. A, fundamental plus 3rd harmonic; B, fundamental plus 3rd and 5th harmonics; C, fundamental plus 3rd, 5th, and 7th harmonics.

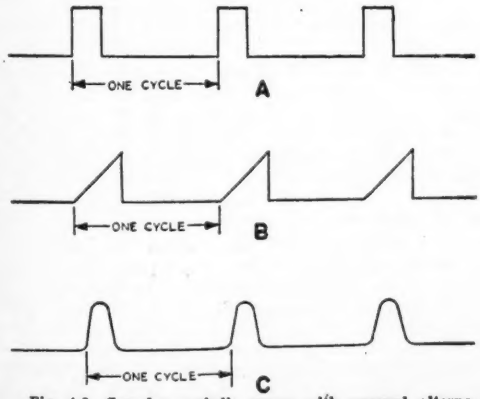


Fig. 4-3. Complex periodic waves with unequal alternations.

Harmonics

A harmonic is a sinoidal wave with a frequency that is an integral multiple of another sinoidal waveform, called the *fundamental.* For example, a sine wave with a frequency of 2000 cps. is the second harmonic of a 1000-cps. fundamental sine wave. Similarly, a 4000-cps. frequency is the fourth harmonic of a 1000-cps. fundamental signal.

A periodic wave is one that repeats itself in definite time intervals. Any complex periodic wave is composed of sine waves of different frequencies and amplitudes, added together. The sine wave which has the same frequency as the complex periodic wave is called the *fundamental,* or first harmonic. For example, Fig. 4-2,A shows a square wave, which has vertical sides and horizontal top and bottom. The sine wave marked "A" has the same frequency as the square wave. Hence "A" is the fundamental frequency. The sine wave "B" has three times the frequency of "A." Hence "B" is the third harmonic.

Square Waves

Fig. 4-2 shows how a square wave is composed of a fundamental and harmonic frequencies. In Fig. 4-2,A the fundamental and its third harmonic are added together to give curve "C," which is only slightly similar to the square wave. In Fig. 4-2,B the fifth harmonic is added to "C," which makes the wave more like the square wave. In Fig. 4-2,C the seventh harmonic is added to the other frequencies, which makes the wave more nearly a square wave.

Note that as more odd harmonics are added, the waveform approaches a square wave. This proves that a square wave consists of the sum of many sine waves. Note also that the amplitude of each harmonic decreases as the order of the harmonic increases. The lower-order harmonics are most important, but the higher order harmonics are required for the shape of the wave. An exact square wave contains an infinite number of odd harmonics. In practice, however, only enough harmonics need be considered to obtain the required accuracy of waveform.

In similar manner, *any* nonsinoidal waveform consists of a fundamental plus harmonics. The fundamental has the greatest amplitude, but the harmonics are required for shape. A *sawtooth* wave contains a fundamental plus odd and even harmonics; a peaked wave, like a square wave, has a fundamental plus odd harmonics.

The shape of any wave depends on the harmonics that are present, their relative amplitudes, and relative phase relationship. In general, the steeper the sides of the waveshape—that is, the more rapid its rise or fall—the more harmonics it contains. Thus, although each of the periodic waveforms shown in Fig. 4-3 consists of the same fundamental plus harmonics, the wave shown in Fig. 4-3,C does not have as many or as large higher-order harmonics as the wave in Fig. 4-3,A.

The wave shown in Fig. 4-3,A is a square wave with unequal alternations—that is, all half cycles are not alike and the wave is not the same on positive and negative excursions. The wave shown in Fig. 4-3,B is a sawtooth wave with unequal alternations. The wave in Fig. 4-3,C is a peaked wave with unequal alternations.

Circuits for Nonsinoidal Waves

Any nonsinoidal waveshape consists of many sine waves of various frequencies and amplitudes. Therefore, it is apparent that if a circuit is to pass a nonsinoidal wave without changing its shape, it must pass all the component frequencies without shifting their relative phases and without changing any of their amplitudes. Such a circuit must have no phase distortion and must be "flat," or have a uniform frequency response to all the frequencies it is required to pass without distortion. As a perpendicular

wave front such as occurs with a perfect square wave is composed of a fundamental and an infinite number of harmonics, it is impossible to pass such a wave through a circuit consisting of practical circuit elements.

Even though it is impossible to design a circuit that will pass a perfect square wave without some distortion, it is possible to design a circuit that has little phase distortion and a flat frequency response from a few cycles to several megacycles. Such a circuit can pass a square wave with only small distortion. Distortion causes the leading and trailing edges of the output wave to be sloped and rounded so that there is a time of rise and fall. This rise and fall time can be made small in properly designed circuits.

Note that the vertical sides of a square wave represent very high frequencies, and that the horizontal portions represent very low frequencies. Thus the square wave can be used to check the overall response of a circuit. If a circuit has the good high-frequency response, it passes

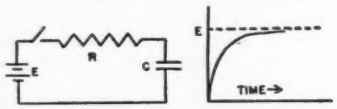


Fig. 4-4. Simple R-C circuit and transient produced by circuit.

the vertical portions without distortion; if it has good low-frequency response, it passes the horizontal portions without distortion. A circuit with good high-frequency and low-frequency response passes the entire square wave without distortion. The square wave is used often to check the response of a circuit to both high and low frequencies.

Instrument electronic circuits sometimes are required to pass complex waveshapes with a minimum of distortion. On the other hand, circuits sometimes are designed to distort a waveform. Two basic and important distortion circuits are the differentiator and integrator circuits. The behavior of these distortion circuits can be understood by examining how these simple circuits produce transients.

Transients and *R-C* Circuits

Fig. 4-4 shows a simple *R-C* circuit—a resistor, capacitor, switch, and d-c. battery in series. At the instant the switch is closed, the capacitor starts to charge the voltage of the battery. The *rate* at which the capacitor charges gradually becomes smaller as the capacitor voltage approaches the battery voltage, as shown on the voltage curve. Although the rate varies, the time for the capacitor to charge to 63 percent of the battery voltage is a constant for any one value of *R* and *C*. Thus, no matter what the voltage of the battery, the capacitor charges to 63 percent of the battery voltage in a time interval called the *time constant*, or *characteristic time*, (*T*) of the circuit. The value of *T* in seconds is the product of the resistor (in ohms) and the capacitor (in farads):

$$T = RC.$$

Note that the charging time increases for an increase in either *R* or *C*.

This simple *R-C* circuit is used often to produce the transient waveform shown, which is called an exponential-rise transient. The formula for the curve is given at the end of this discussion.

On discharge, the circuit reacts similarly. For example, if the battery in Fig. 4-4 is replaced by a solid conductor, the charged capacitor discharges 63 percent of its charge in *RC* seconds.

The simple *R-C* circuit shown in Fig. 4-4 is important because it can be either a coupling circuit, a differentiator, or an integrator—depending on the values of *R* and *C*. Thus it is important to examine the circuit in detail.

In *RC* seconds, the capacitor charges to 63 percent of the applied voltage. In the next *RC* seconds, the capacitor charges to 63 percent of the remaining charge, or to 87 percent of the applied voltage. In the 3rd interval of *RC* seconds, the capacitor charges to 95 percent of the applied voltage. Although the capacitor never charges to exactly 100 percent of the applied voltage, it charges to 99 percent of the applied voltage in 4.6 *RC* seconds, as shown in Fig. 4-5, which is a curve of capacitor voltage (or current) versus time. Note that time is plotted in *RC* units.

Curve A in Fig. 4-5 is the capacitor voltage while the capacitor is charging. Curve B is the current in the circuit while the capacitor charges. Curve B also represents the current and voltage during discharge.

Transients and *R-L* Circuits

If the capacitor in Fig. 4-4 is replaced by an inductor, the voltage across the inductor is a maximum (E) at the instant the switch is closed, and then decreases to zero

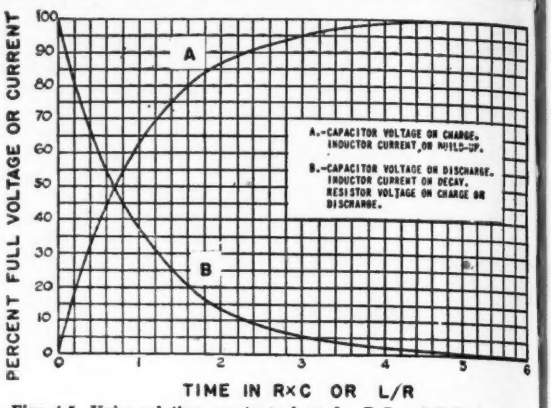


Fig: 4-5. Universal time constant chart for R-C and R-L circuits.

slowly, as on curve B of Fig. 4-5. The reason the inductor voltage decreases to zero is because the inductor has no d-c. resistance. Thus, there is voltage across the inductor only when the current is changing. The current in the *R-L* circuit is represented by curve A in Fig. 4-5. Thus the curves on Fig. 4-5 represent the current and voltage in both the *R-C* and *R-L* circuits. These curves are known as *universal time-constant charts*. The charts tell what value of *R* and *C* (or *L*) are required to produce an exponential signal which rises to any given amplitude in any given time. Timers make use of circuits and signals of this type.

The *R-L* circuit has a characteristic time constant similar to that of the *R-C* circuit. The time constant of the *R-L* circuit is defined as the time required for the current through the inductor to increase to 63 percent of the maximum current, or to decrease to 37 percent of the minimum current. The time constant of the *R-L* circuit is *L/R*, that is,

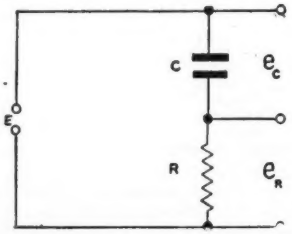


Fig. 4-6. R-C circuit, showing voltage-dividing effect.

$$T = L/R$$

where *T* is the time constant in seconds, *L* is the inductance in henrys, and *R* is the resistance in ohms.

As the shapes of the curves for current and voltage in the *R-L* circuit are exactly the same as in the *R-C* circuit, the universal time-constant chart can be used for both circuits.

Characteristic Time Constant and A-C. Response

The transient response of the *R-C* and *R-L* circuit to a d-c. signal depends on the characteristic time constant

of the circuit. Similarly, the response of the circuit to a sinoidal a-c. waveform or to any periodic waveform depends on the characteristic time constant.

Fig. 4-6 shows the simple *R-C* circuit. Consider the response if a signal generator connected to the input (E) delivers a 1000-cps. sinoidal signal to the circuit. Note that the duration of one cycle of the 1000-cps. wave is 1/1000 second, or 1000 microseconds.

If the resistance of the resistor is much greater than the reactance of the capacitor, all the generator voltage appears across the resistor—that is, the circuit is like a voltage divider in which the resistance is so much larger than the reactance that the capacitor voltage is negligible. This occurs when the resistance is large and the capacitive reactance is small—that is, when the capacitance is large.

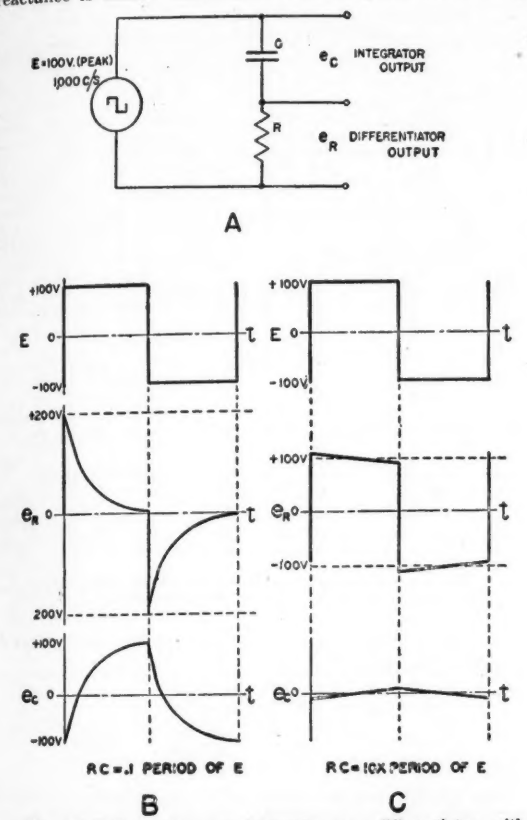


Fig. 4-7. R-C circuit as an integrator or a differentiator, with a square-wave input. A, circuit; B, action when time constant is smaller than the period of the input; C, action when time constant is larger than the period.

The action of the *R-C* circuit always can be understood by considering the voltage-dividing effect.

Another way of saying the same thing is to say that if the characteristic time constant of the circuit is more than five times the duration of one cycle (1000 microseconds), then the entire generator voltage appears across the resistor. Such a circuit is a good *coupling* circuit. In a coupling circuit the capacitor merely couples the signal to the resistor. As there is insignificant *IX* drop across the capacitor, the generator signal appears across the resistor unchanged in *voltage or phase*.

However, if the characteristic time constant of the circuit is reduced either by reducing the capacitor, the resistor, or both, the voltage (*IX*) across the capacitor increases, and that across the resistor (*IR*) decreases. This is because an *R-C* circuit with a short time-constant has a small resistance and a high reactance. The circuit then is a voltage divider in which only a small signal appears across the resistor and a large signal across the capacitor. If the signal is a pure sine wave, the voltage across the resistor is changed in phase, but is otherwise undistorted. If the signal is not a pure sine wave, the signal across the resistor is distorted.

The amount of voltage division and distortion (or the shift in phase) depends on whether the characteristic time constant is much smaller than the period of the signal. If it is, the circuit acts as a differentiator.

Differentiation

A differentiator is a circuit whose output is proportional to the *rate* of change of the applied signal. Consider the action of the circuit of Fig. 4-6 if the time constant is much smaller than the period of the applied signal. This occurs when the capacitor is small—that is, when the reactance of the capacitor is much greater than the resistance of the resistor. Hence only a small part of the applied voltage appears across the resistor because of the voltage-dividing action of the circuit. However, the reactance of the capacitor depends on the frequency of the applied signal. Therefore, the amount of signal appearing across the resistor depends on the *rate* of change of the applied signal. Hence the circuit is a differentiator. Note that the only difference between a differentiator and a coupler is in the time constant of the circuit.

Fig. 4-7 shows the simple *R-C* circuit with an applied square wave. The voltages across the resistor and capacitor are shown for both a short-time-constant circuit and a long-time-constant circuit. The differentiator output is across the resistor. For good differentiation the time constant of the circuit should be much smaller than the period of the applied signal. If it is not, the applied signal appears undistorted across the resistor, as shown in Fig. 4-7,C, and the circuit is a coupling circuit.

Integration

An integrator is a circuit which adds, or one which produces an output voltage which is proportional to the area under the curve of an applied voltage. The circuit shown in Fig. 4-4 is an integrator if the time constant is *long* compared to the period of the applied signal. When the time constant is long, the capacitor charges slowly and linearly with the applied voltage, as shown by the bottom curve in Fig. 4-7,C. Note that the circuits in Figs. 4-4, 4-6, and 4-7 are essentially the same. Fig. 4-4 is the conventional way of representing an integrator. However, the integrator output of Fig. 4-7 is exactly the same. Note that the integrator output of Fig. 4-7 is exactly linear when the time constant is long. Hence it is proportional to the area under the curve of the applied voltage.

Note that the differentiator, the integrator, and the coupler are similar *R-C* circuits. A good integrator circuit has a time constant much longer than the period of the applied signal, and the output is across the capacitor. A good differentiator has a time constant much shorter than the period of the applied signal, and the output is across the resistor. A good coupling circuit has a time constant much longer than the period of the applied signal, and the output is across the resistor.

The simple *R-C* circuit is important. Depending on its time constant, it is either a coupler, a differentiator, or an integrator. It is used in instrument circuits in all three ways. Even more important is the fact that as a signal goes from stage to stage through an electronic circuit, the effect of the circuit on the signal depends on the equivalent *R-C* value of the point in the circuit. Hence it is important to understand how the simple *R-C* circuit operates.

Integrators and differentiators are used widely in instrument circuits. The integrator is used in counting and adding. The differentiator is used to shape signals. Fig. 4-8 shows how a differentiator changes the shape of applied signals. In Fig. 4-8,A the slope of the trailing edge of the sawtooth voltage is greater than that of the leading edge; therefore, the amplitude of the output voltage, e_R, is greater during this portion of the cycle. The amplitude of the output voltage depends on the steepness of the input-voltage rise or decay (rate of change of signal), as shown in all curves in Fig. 4-8.

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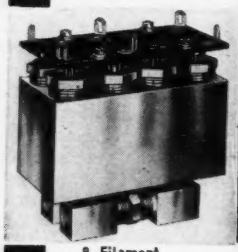

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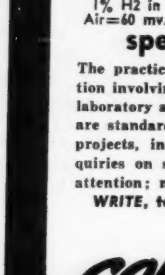

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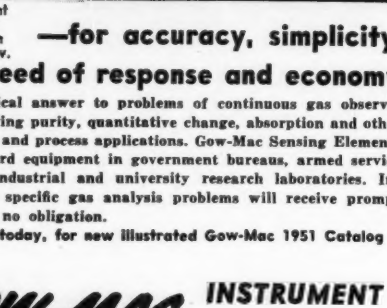

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Formula for Exponential Transient. The formula for the exponential curve in Fig. 4-4 is:

$$V = E(1 - e^{-kt}),$$

where V is the voltage across the capacitor at any time, t; t is the time in seconds from the instant that voltage E is applied; E is the applied voltage; e is 2.718, or the base of natural logarithms; and k is a constant.

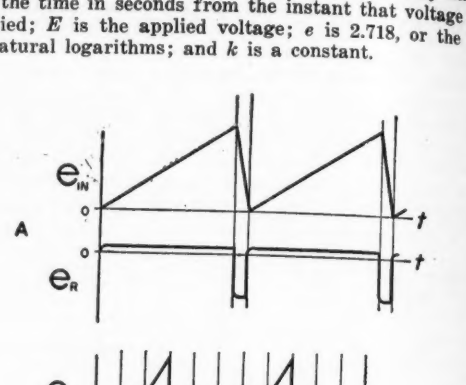

Fig. 4-8. Differentiator output of a circuit with a short RC time constant for various input waveshapes.

The value of the constant, k, for the circuit in Fig. 4-3 is $1/RC$. Therefore,

$$V = E(1 - e^{-t/RC}).$$

Note that when $t = RC$ seconds:

$$V = E(1 - e^{-1})$$
$$= E(1 - 1/2.718)$$
$$= 0.632E$$

This proves that no matter what the applied voltage, at the time $t = RC$ seconds, the voltage across the capacitor of the R-C circuit is 63.2 percent of the applied voltage.

TEST ITEMS FOR—IV. SIGNALS & SIMPLE CIRCUITS

4-5. The displacement of a diawhich
- (a) has self induction
- (b) has a primary and secondary coil
- (c) changes the form of energy
- (d) changes the amplitude of energy

4-2. Which of the following is NOT a transducer?
- (a) Electron tube
- (b) Thermocouple
- (c) Photoelectric cell
- (d) All the above

4-3. A signal is a change in
- (a) voltage
- (b) current
- (c) frequency
- (d) any of the above

4-4. A pressure-sensitive primary element with resistance R changes resistance when compressed. The signal output is a
- (a) voltage equal to IR
- (b) change in the IR voltage
- (c) displacement of a diaphragm
- (d) displacement of the element

4-5. The displacement of a diaphragm or Bourdon tube can be used to produce an input signal to an electronic instrument by producing a change in
- (a) resistance
- (b) capacitance
- (c) inductance
- (d) any of the above

4-6. A common primary element used in counting circuits is the
- (a) photoelectric cell
- (b) strain gage
- (c) carbon pile
- (d) thermocouple

4-7. A radar measures distance by measuring the
- (a) voltage amplitude of a transmitted r-f. pulse
- (b) voltage amplitude of an echo pulse
- (c) time between transmitted r-f. pulses
- (d) time between an r-f. pulse and its echo

4-8. In order to make a frequency-response curve of a circuit, the input should be varied in
(a) both voltage and frequency
(b) neither voltage nor frequency
(c) frequency only
(d) voltage only

4-9. A harmonic is
(a) an integral multiple of a fundamental
(b) an integral multiple of a 1000-cps. signal
(c) the lowest-frequency component of a signal
(d) the highest-frequency component of a signal

4-10. A fundamental is
(a) an integral multiple of a harmonic
(b) a 1000-cps. signal
(c) the lowest-frequency component of a signal
(d) the highest-frequency component of a signal

4-11. The shape of any complex wave depends on the
(a) number of harmonics
(b) relative amplitudes of each harmonic
(c) phase relationship of harmonics
(d) all the above

4-12. A pure sine wave has
(a) no harmonics
(b) no fundamental
(c) an infinite number of harmonics
(d) a small number of harmonics

4-13. A square wave has
(a) no harmonics
(b) no fundamental
(c) an infinite number of harmonics
(d) a small number of harmonics

4-14. Which portion of a square wave is undistorted by a circuit with good low-frequency response?
(a) The horizontal top and bottom
(b) The vertical sides
(c) The entire waveform
(d) The amplitude

4-15. The characteristic time constant of an R-C circuit in which the capacitor charges through the resistor is the time for the capacitor to charge to
(a) 100 percent of an applied d-c. potential
(b) 100 percent of an applied a-c. potential
(c) 63 percent of an applied d-c. potential
(d) 63 percent of an applied a-c. potential

4-16. A capacitor of 1 microfarad capacity is being charged through a resistor by a 100-volt battery. What size resistor (in ohms) must be used if the capacitor is to charge to 99 volts in exactly 1.84 seconds?
(a) 0.4
(b) 21.5
(c) 25,000
(d) 400,000

4-17. The characteristic time constant of an R-L circuit is
(a) RL
(b) L/R
(c) R/L
(d) 1/RL

4-18. When an R-C circuit has a characteristic time constant that is much longer than the period of an applied a-c. signal, the signal across the resistor is
(a) distorted
(b) amplified
(c) larger than that across the capacitor
(d) changed greatly in phase by the circuit

4-19. The voltage-dividing action of an R-C circuit causes most of an applied a-c. signal to appear across the capacitor when the characteristic time constant is
(a) RC
(b) 1/RC
(c) much smaller than the period of the applied signal
(d) much larger than the period of the applied signal

4-20. A circuit whose output is proportional to the rate of change of a signal is called
(a) a differentiator
(b) an integrator
(c) an amplifier
(d) a coupler

4-21. An R-C circuit has a long time-constant and the output is taken across the resistor. The circuit is
(a) an integrator
(b) a differentiator
(c) a coupler
(d) any of the above

4-22. An R-C circuit has a long time-constant and the output is taken across the capacitor. The circuit is
(a) an integrator
(b) a differentiator
(c) a coupler
(d) any of the above

4-23. An R-C circuit has a short time-constant and the output is taken across the resistor. The circuit is
(a) an integrator
(b) a differentiator
(c) a coupler
(d) any of the above

4-24. The circuit which produces a sharply peaked output whenever the input signal changes rapidly is the
(a) integrator
(b) differentiator
(c) coupler
(d) any of the above

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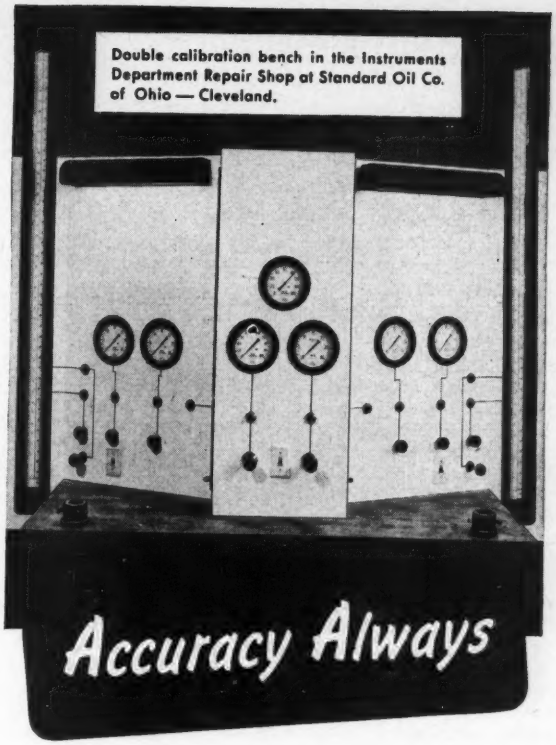
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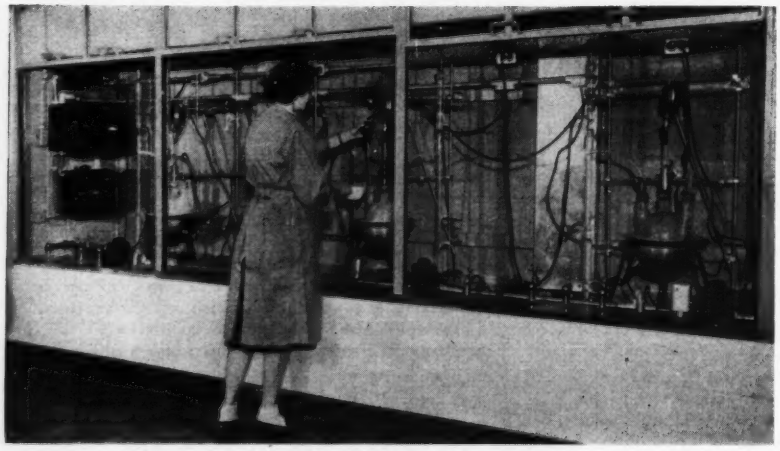
Instruments Automatize a Paint Company's Product-development Tests

METUCHEN, N. J.—Drastically cutting potential instrument costs with the same stroke that slashes both operation and labor time—such is the accomplishment of the Socony Paint Products Co. with the help of Tagliabue Instruments Division of Weston Electrical Instrument Corp. Socony, which manufactures synthetic resins and varnishes, was confronted with a problem of automatically controlling four quantitative tests simultaneously in its pilot plant. Since the tests were conducted manually, the question was: How to shift most efficiently and economically from manual control to control by instrumentation. The answer: A unique variation of a "TAG Celectray Multiple Point Indicating Controller" with only one "TAG Program Unit." The resulting installation is the only one of its kind that can be used to control four tests employing the same program for uniform results.

In Socony's manually-controlled tests, four miniature stills were filled with varying quantities of materials, heated by line current and put through a reflux system according to a definite program. Temperatures were indicated by four bimetallic thermometers; temperature control was done manually by means of four "Variacs," one for each still.

In switching from manual to automatic control, ordinarily four controllers and four program units would be necessary. By using the "TAG" instruments, however, the company found that only one controller—a four point potentiometer with thermocouples placed in each still—and one program unit could do the job at a considerable savings in instruments costs. As a result, the entire operation can be controlled automatically after the program is set up, with only two instruments instead of eight. The only manual labor involved is adding various solvents at defined stages in the program according to the conditions of the test being conducted.



Pilot plant of Socony Paint Products Co., Metuchen, N. J., boasts unique installation of instruments for conducting product-improvement tests on synthetic resins and varnishes. Two instruments (at left) automatically control the simultaneous heating of the four stills (one is hidden behind operator) filled with varying quantities of alkyd resins, phthalic anhydride, glycerine, vegetable oils, and other materials.

Durable Pigment for Clinical Thermometers

WASHINGTON, D. C.—As the result of research at the National Bureau of Standards, a durable, lasting pigment is now available for marking clinical thermometers. Developed by R. J. Welch and F. W. Reinhart of the NBS staff, the new marking compound is a silicone resin formulation that withstands cleansing with soap and phenol solutions far better than any other known pigment.

Thermometers used in hospitals must undergo constant immersion in detergents or soap solutions and germicides such as phenol. Loss of pigment due to the action of these cleansing agents has been a major cause of thermometer failure. The Hospital Bureau of Standards and Supplies and the American Hospital Association therefore requested the National Bureau of Standards to make a study of the situation with a view to the development of a pigment that would withstand normal hospital usage. A large number of formulations were investigated, as well as various methods of etching. Finally the new silicone formula was developed, and long-term immersion tests showed that it was the answer to the problem.

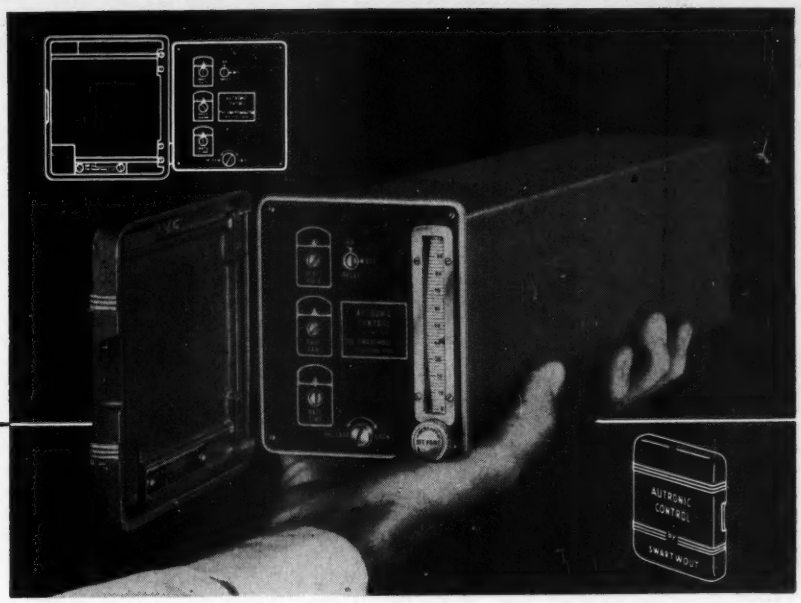
Controlled Humidity for Research

WASHINGTON, D. C.—Convenient means of producing and maintaining atmospheres of known relative humidity at any of the temperatures encountered in a radiosonde flight has been developed at the National Bureau of Standards, according to Technical Report 1512. A recirculating type of apparatus was devised for calibration and research purposes by A. Wexler and associates of the Bureau's mechanical instrument laboratory under the sponsorship of the Navy Department's Bureau of Ships.

The need for such a device results from the use of the electric hygrometer for measuring water vapor content of the air during a meteorological sounding of the upper atmosphere by means of the radiosonde. During a flight, the hygrometer may be subjected to a wide range of temperatures and humidities, as well as air flows, corresponding to balloon ascent rates of 1000 fpm. or more. The new equipment was designed primarily for operation at temperatures above freezing, but is equally useful at temperatures down to −40 C. Provision was made for obtaining discrete changes in humidity and temperature and for maintaining given air speeds up to 1500 fpm. The recirculating apparatus supplements equipment previously developed at the Bureau for use at temperatures below freezing.

A known relative humidity is produced by saturating a stream of air with water vapor at a given temperature and then raising the temperature of the air to a specified higher value. The relative humidity, at the higher temperature, is the ratio of the saturation pressure of water vapor at the lower temperature to the saturation pressure of water vapor at the elevated temperature. A gas pump circulates air from a saturator into a test-chamber and then back into the saturator. Complete saturation is achieved, simply and efficiently, by recirculating the air over water or ice in the saturator, in a closed system.

The temperature of the saturator is maintained constant by a thermostatted liquid bath while that of the test-chamber is controlled by means of a heater in the air stream. This is possible be-



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cause the air from the saturator must necessarily be brought to a higher temperature and hence the only requirement for achieving any desired test-chamber temperature is the introduction of the requisite amount of heat into the air stream.

Features of the saturator are its simplicity of design, its adaptability for temperatures below as well as above the freezing point of water, and its effective saturation at both high and low flows. These are achieved in large measure by imparting a centrifugal action to the entrant air stream. The saturator is a cylindrical chamber containing distilled water to a convenient depth. Air is discharged through a nozzle into the chamber above the water surface and tangential to the vertical walls and then exhausted through a central port in the top. The centrifugal action creates a whirlpool which greatly increases the liquid surface and thoroughly mixes water vapor with the air. Spray and liquid droplets are forced to the walls by centrifugal force which results in little tendency for liquid water to emerge through the exit port except at low flows. Under these conditions, a multilayer fine wire screen baffle at the exit traps and prevents water from passing out of the saturator. Since air does not bubble through water but only passes over its exposed surface, the water may be frozen without impairing the functioning of the saturator.

Rapid and discrete changes in relative humidity are achieved by utilizing four independent but identical recirculating systems, arranged so that their test chambers may be interchanged easily and quickly. Thus, if a different temperature is maintained in each of the four saturators, and if the same temperature is maintained in each test chamber, the relative humidity in each test chamber is different. By interchanging the test chambers, the relative humidities therein undergo discrete changes as each test chamber communicates with a different saturator.

The interchange of test chambers is effected by a pneumatic switch consisting of two ground and lapped plates to which are attached air lines leading from the saturators to the test chambers. A quarter-turn of the top plate with respect to the bottom plate advances each test chamber to a new position and connects each test chamber with a different saturator. The relative humidity can be changed in one to two seconds, according to the speed with which the switch can be rotated.

The gravimetric method of moisture determination was employed to check the accuracy of the apparatus. Measurements of the relative humidity produced in the test chamber were made over a wide range of test chamber temperatures, relative humidities, and air flows. The results reveal an average difference in relative humidity of ±1.2 percent between the relative humidity measured by the two techniques. As an additional check, a thermocouple psychrometer was employed to measure the actual relative humidity in the test chamber. These results show an average difference of ±0.9 percent between the psychrometric and the apparatus relative humidity measurements.

Photographic-film Dosimeter

WASHINGTON, D. C.—A compact film-badge has been developed by the National Bureau of Standards for industrial safety programs and for monitoring in civilian defense, according to Technical Report 1542.

Ideally, a film dosimeter should (1) indicate the quantity of radiation, or dosage, and (2) be independent of the size of radiation quanta. The NBS film badge is designed to monitor gamma and X-radiation in the quantum energy

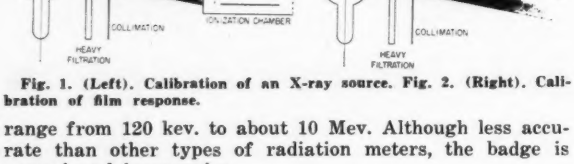

Fig. 1. (Left). Calibration of an X-ray source. Fig. 2. (Right). Calibration of film response.

range from 120 kev. to about 10 Mev. Although less accurate than other types of radiation meters, the badge is rugged and inexpensive.

The maximum total dosage to which any part of the human body should be exposed continuously or intermittently in one week is currently set at 0.3 roentgen. Exposure effects are cumulative, however, and a continuation of slight overexposure can become dangerous. Although Geiger-Mueller counters and similar radiation meters are used widely, they are too cumbersome for periodic personnel-type monitoring. The small film badges, on the other hand, are suited for this type of monitoring.

The NBS film badge can monitor radiation intensities from 0.5 to 10,000 roentgens. It can be used to obtain a permanent record of the radiation exposures received by structures and individuals in critical areas resulting from industrial accidents or national disasters.

The film badges are calibrated with X-radiation energies from 115 kev. to 10 Mev. The accuracy limits within the ranges from 1 to 50 roentgens and from 500 to 10,000 roentgens are ± 12 percent. In the center range, from 50 to 500 roentgens, the accuracy limits are ± 20 percent.

In calibrating the badges, it is necessary to have a calibrated source of radiation. Fig. 1 shows the calibration of a constant-potential X-ray source. Reference dosages were determined by directing radiation from the source (left), through a heavy absorber of known characteristics, and into a free air-ionization chamber.

Fig. 2 illustrates the technique used to determine the response of film exposed to calibrated X-radiation over the range of film sensitivity and radiation energy. The radiation is directed to the film through an absorber and collimating slit.

Fig. 3 shows the film processing. After 5 minutes in the developer, where it is agitated mechanically, the film is kept in an acid stop bath for 10 seconds, a fixer solution for 10 minutes, and a water wash for 20 minutes.

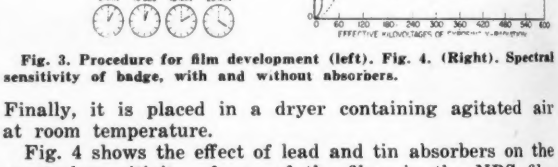

Fig. 3. Procedure for film development (left). Fig. 4. (Right). Spectral sensitivity of badge, with and without absorbers.

Finally, it is placed in a dryer containing agitated air at room temperature.

Fig. 4 shows the effect of lead and tin absorbers on the spectral sensitivity of one of the films in the NBS film badge. The absorber thicknesses chosen are a compromise for all possible variations in radiation energy and film type.

Join Forces to Develop New Industrial X-ray Process

MILWAUKEE, Wis.—Commercial development of xeroradiography—a new process that may greatly reduce the use of films and darkrooms in industrial x-ray work—is the object of a joint program launched by three organizations—The Haloid Company of Rochester, N. Y., Battelle Memorial Institute, Columbus, Ohio, and General Electric X-Ray Corporation, Milwaukee, Wisconsin.

Xeroradiography is expected to make x-ray inspection faster and more economical so that it can be utilized in many more industrial fields, particularly in smaller foundries, machine shops, and general metal-working firms. It may also have value in the inspection of ordnance and other war material, and in the field of medical diagnosis.

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12214 South Lakewood Blvd.
Downey, California

REVOLUTIONARY

Rotomotor

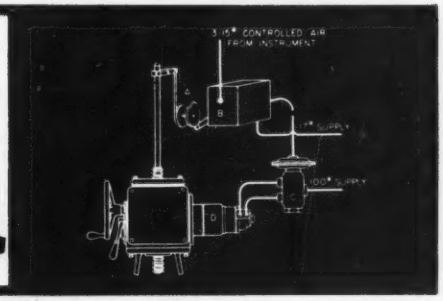
WINS REFINERY ACCEPTANCE

New All-Pneumatic Slide Valve Operator
Cuts Costs on Fluid Catalytic Cracking Units

This new air-operated Rotomotor makes it unnecessary to invest the heavy capital required for hydraulic systems. Using ordinary plant air supply, the Rotomotor is more economical for operating slide valves in control of spent catalyst, regenerated catalyst, and back pressure of flue gas on stack valves. In addition to being dependable, rugged and compact, the Rotomotor is accurate and sensitive to instrument output pressure changes as small as .025 psi.

It is capable of handling thrust loads up to 60,000 lbs. with stem travels up to 36". It is inherently a self-locking mechanism because it operates through a gear drive and threaded stem. A continuously connected handwheel and declutching lever provide for manual operation if needed.

Rotomotors may be mounted on any catalyst slide valve of your choice at the manufacturer's plant and shipped to you as complete units ready for installation.



ACCEPTED BY THESE MODERN REFINERIES

- Skelly Oil Company
- Taylor Refining Company
- Imperial Oil Ltd.
- British American Oil Co.
- Cities Service Oil Company
- The Texas Company
- Canadian Oil Refinery Ltd.
- Dunkirk Refinery (France)

HOW IT WORKS:

POSITIONING DEVICE (B) determines *actual* valve stem position by means of tape and cam connection (A) and *desired* stem position by air impulse from control instrument. Corrected output air pressure from (B) then is fed to AUXILIARY PILOT (C) which ports main air supply to PNEUMATIC MOTOR (D) driving gear box clockwise or counterclockwise repositioning stem and completing pneumatic control loop.

Write for New Bulletin I

Cono-Controls

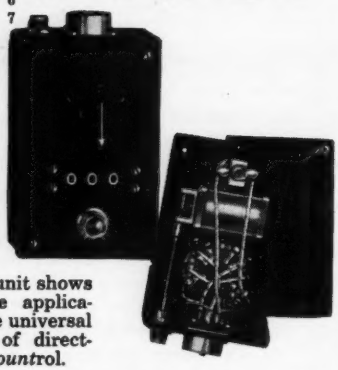
CONOFLOW CORPORATION
2100 ARCH STREET • PHILADELPHIA 3, PENNA.

Small Component... or Complete Unit... You Can Count on getting whatever You need—Added evidence that

Everyone Can Count on

VEEDER-ROOT

This REEL CONTROL BOX, complete with its *built-in* counting mechanism, indicates the number of feet of antenna reeled in and out of certain types of military aircraft. Manufactured completely by Veeder-Root, including outside bakelite cover and box, this unit shows another imaginative application of the universal language of direct-reading *Count*rol.



VEEDER-ROOT INCORPORATED
HARTFORD 2, CONN.

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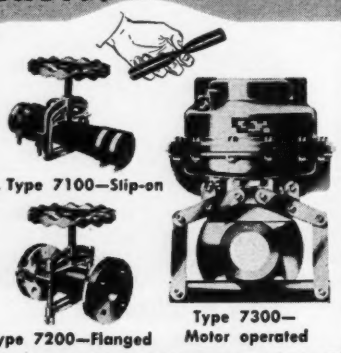
if it Flows . . .



Type 7100—Slip-on

Type 7200—Flanged

Type 7300—Motor operated

Acids
Asbestos
Brines
Chips
Paper Stock
Slurries
Wood Stock
Non-Metallic Minerals

Flex-Valve it

FLEX-VALVE is the ideal choice for handling such materials as those listed—either dry or in suspension—at temperatures up to 210 deg.

Resists both abrasion and corrosion; eliminates clogging, plugging, building up; absorbs vibration and misalignment.

Open—it's as free of obstruction as the pipe itself. Closed—it's bubble-tight and it closes tight on all of these materials.

Available in either hand or air operated types in sizes from ½ to 12 in.

Users have found FLEX-VALVE to be the low-cost solution to tough valving problems. If your present valves aren't 100% effective, take a look at this one. Catalog 455 gives details.

Flexible Valve Corporation

336 COMMERCIAL AVE. • PALISADES PARK, N. J.

fast, low-cost, dry, direct-positive process for producing x-ray images. It is electrostatic, rather than chemical. Reusable plates and low-cost powders take the place of chemicals and films used in conventional radiography. In less than two minutes, with a minimum of effort, an industrial inspector can secure a "shadow" picture similar to that on an x-ray negative, showing the internal condition of his product.

Xeroradiography has advantages over rapid film development processes in that it is entirely free of chemicals and employes re-usable plates. Another advantage is that neither the image nor the xerographic plate is affected by any type of radiation, including atomic radiation.

Xeroradiography is being developed at Battelle under Haloid-Battelle sponsorship. General Electric X-Ray is cooperating in the project and will market the equipment, when perfected. The new process is an outgrowth of xerography, a method for producing fast, low-cost copies of anything written, printed, or drawn, using light rather than x-rays. Xerography, already commercially available, is a product of The Haloid Company.

DECHEMA

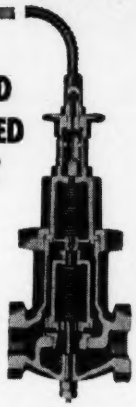
In May 1951 an Information Meeting was arranged by the DECHEMA (Deutsche Gesellschaft fuer Chemisches Apparaturesen E.V.) in cooperation with the Process Industry committee of the Vereins Deutscher Ingenieure in Frankfort, Germany. The meeting was attended by 3000 chemists, engineers, and chemical engineers. The purpose of the meeting was to encourage and to promote discussion between the manufacturers and users of chemical apparatus. Discussion booths were set up by 180 important manufacturers in the Meeting Halls of the City of Frankfort. The booths were manned by high-calibre specialists and technicians.

The companies showed models and illustrations of their equipment; these were used in the discussions. Fig. 1 shows a part of the hall, which was divided into four divisions: (1) Laboratory apparatus, (2) instruments and controls, (3) large equipment, and (4) materials. Fig. 2 shows the models of chemical equipment in one booth.

The Information Meeting was not an exhibit of apparatus,

Continued on page 1342

SELF -CONTAINED -CONTROLLED -SUFFICIENT -RELIANT



Stacon Temperature Regulator*

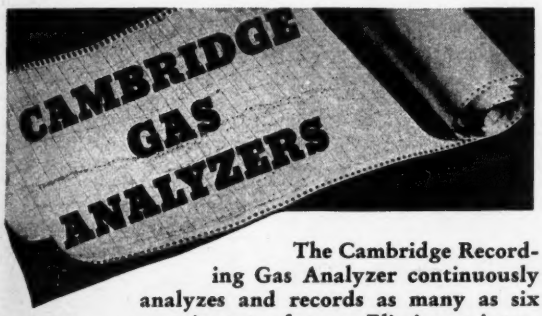
The patented Farris Stacon Temperature Regulator is easily the most independent regulator available today. It's unique. It stands alone. It's trustworthy. It needs no watching. It's perfect for the man who wants no cause for worry . . . who wants to relax in the sure knowledge that his temperatures are constant.

Here's why Stacon stands alone in the field. It has no packing glands to leak or bind . . . the stem moves freely. The liquid in the bulb flashes to vapor in the power bellows, assuring hairtrigger response to move the disc. It operates with unbelievable accuracy—to within plus or minus 1 degree—and it operates with that accuracy under *all* conditions. Stacon provides air-operated accuracy at low, self-operated cost.

Get the details on the one truly outstanding temperature regulator—Stacon. Send for Bulletin 50-1000 to get all the details.

*Patented and Patents Pending

Farris Stacon Corporation
536 COMMERCIAL AVE. PALISADES PARK, N. J.

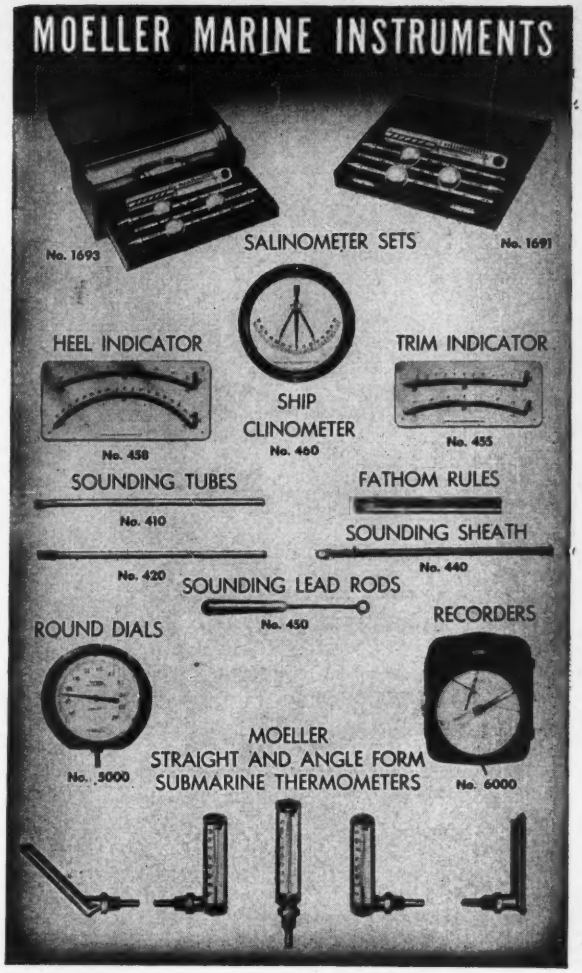


The Cambridge Recording Gas Analyzer continuously analyzes and records as many as six constituents of a gas. Eliminates intermittent, slow and expensive manual gas analysis. Accurate . . . Sensitive . . . Simple. No moving parts; utilizes thermal conductivity principle.

Makes possible substantial savings in the operation of kilns, production of inert gases, and in metallurgical, petroleum, and other chemical processes. Single- and Multi-point instruments are available for a wide variety of applications.

Send for literature mentioning application

CAMBRIDGE
INSTRUMENT COMPANY, INC.
3742 Grand Central Terminal, New York 17
Pioneer Manufacturers of
PRECISION INSTRUMENTS



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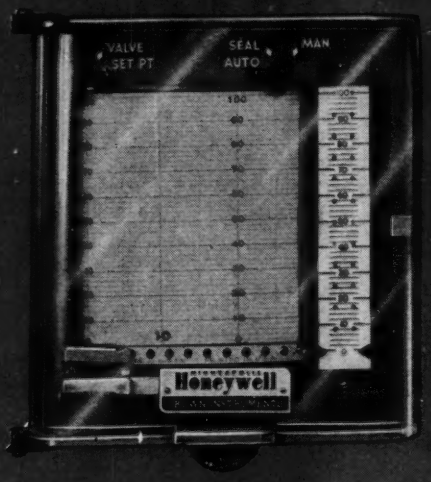
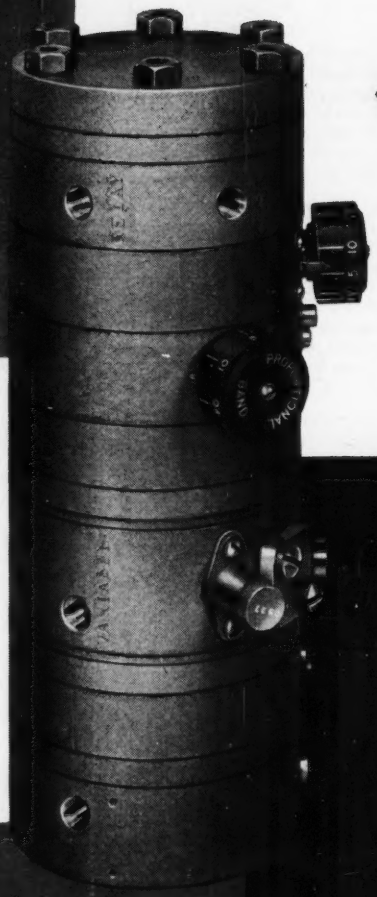


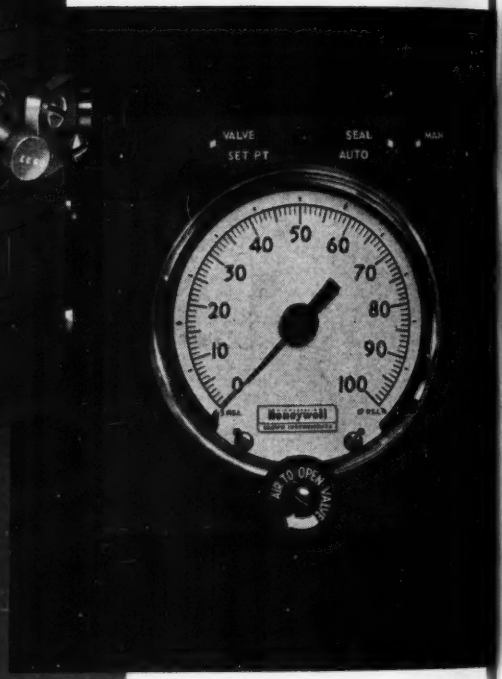


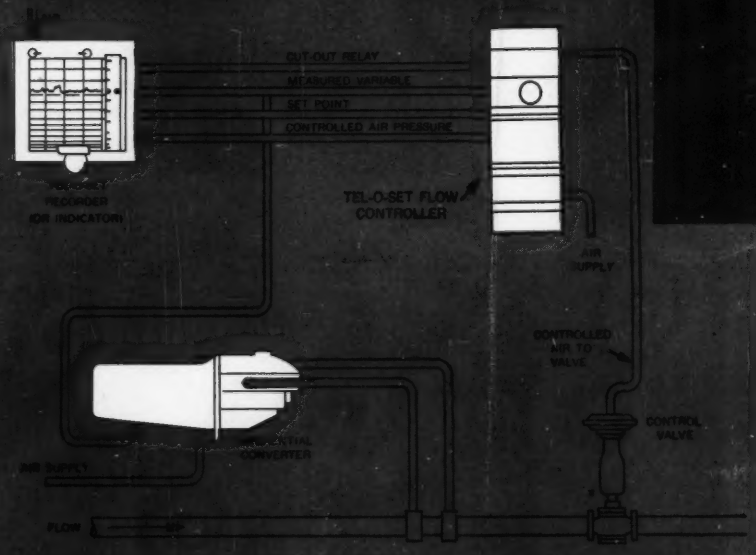
TEL-O-SET CONTROLLER

Available in adjustable and fixed proportional band models, and with three control forms . . . for flow, temperature, pressure, level and other process variables. Universal bracket permits optimum flexibility in mounting . . . coded, interchangeable sections and split manifold contribute to simplified maintenance. Write for Specification Sheet No. 768.

TEL-O-SET RECORDER

Features withdrawal of chassis for full 8-hour chart visibility without interrupting operations, bumpless shifting from automatic to manual operation, all adjustments from front of panel, built-in adjustable restrictions for pulsating flow . . . requires panel space just 5 1/16" high by 5" wide. Write for Specification Sheet No. 769.





TYPICAL ENGINEERED *TEL-O-SET* CONTROL SYSTEM—Pictured in this diagram are the elements of the *Tel-O-Set* Family, designed and built as an integrated loop. Here the system is applied to the control of flow with the *Differential Converter* used as transmitter.

TEL-O-SET INDICATOR

Can be used with any pneumatic transmitter, having a 3-15 psi controlled air output, regardless of the primary element being used. Provides indication of process variable, set-point of controller or controlled air pressure to valve when on automatic control . . . is easily shifted to manual operation. Panel cut-out size same as recorder. Write for Specification Sheet No. 770.

. . . Contribution to Process Control

. . . THE HONEYWELL TEL-O-SET FAMILY

THIS pace-setting pneumatic control system is ready for application to a host of processes demanding a new high in speed, precision and accuracy . . . for almost any process variable. Developed as part of a family relationship, each unit complements the others in producing a system of superior performance.

Used with any one of a group of Honeywell measuring elements . . . for flow, temperature, pressure, liquid level, etc. . . . the *Tel-O-Set* system is destined to make important contributions to the improvement of process control throughout industry.

For more detailed information, send for the literature mentioned in the descriptions at left . . . or call in our local engineering representative for a discussion of your process control problems.

MINNEAPOLIS-HONEYWELL REGULATOR Co., *Industrial Division*, 4482 Wayne Ave., Philadelphia 44, Pa.

MINNEAPOLIS **Honeywell**

Brown Instruments

H HONEYWELL

The Month's NEW INSTRUMENTS

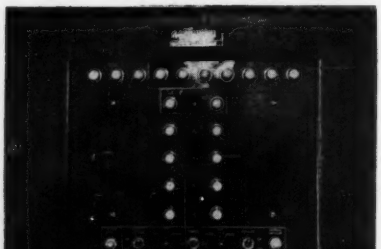
In this department we report each month new devices for measurement, inspection, testing, computing, metering and automatic control—in the form of concise technical descriptions.

FOR FURTHER INFORMATION USE THE POSTAGE-FREE ORDER CARD ON PAGE 1373

Temperature Scanning System

New "ElectroniK" scanning system continuously and automatically monitors up to 270 separate temperature points and records only temperatures which deviate beyond pre-set limit. System comprises recorder, rectifier, stepping-switch control unit (illustrated), and alarm for when temperature of any point exceeds limit. Operator selects type of operation—(1) temperature recorded only when set point is exceeded, (2) temperatures recorded continuously, (3) no temperatures recorded but scanning continues, and (4) only manually selected points recorded. Scanning rate is one point per second. Manual control is available to operator.—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Philadelphia 44, Penna.*

Mention No. 1101 when filling out card.



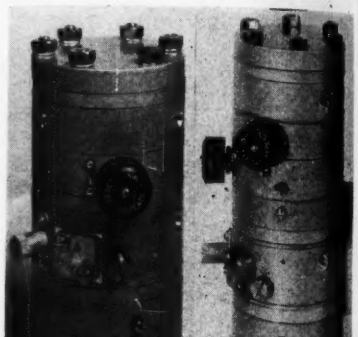
Web-material Controller

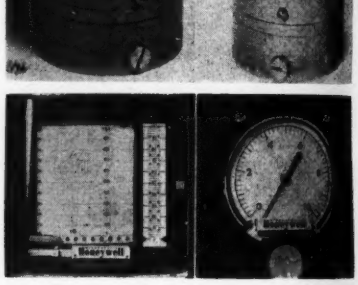
New edge controller for registering web material during processing uses mechanical sensing finger and differential transformer to control hydraulic servopositioning system. Electric-hydraulic control positions to within 0.001 in. over range of 3 in., with only ¼ oz. pressure on edge of web, while web material travels at 100 yds. per min.—*Automatic Temperature Control Co., Inc., 5200 Pulaski Ave., Philadelphia 44, Penna.*

Mention No. 1102 when filling out card.

Unitized Control System

New "Tel-O-Set" pneumatic control system consists of small, easily serviced, interchangeable units. New units, which can be used with maker's differential converter in integrated system, include controller, recorder, and indicator. Small size of recorder and indicator (bottom) makes them particularly useful on graphic panels. Controller is available in two models—with fixed proportional band (top left) and with adjustable proportional band (top right). Controller units are constructed of a number of coded, interchangeable units separated by diaphragms. Except for manual adjustments of reset, controllers operate wholly in response to pneumatic signals. Air-supply pressure is 20 psi.; output pressure is 3-15 psi. Proportional band is either 150 percent (fixed) or adjustable between 2 and 150 percent. Reset is adjustable from 0.2 to 100 repeats per minute or from 0.01 to 5 repeats per minute (on adjustable band controller only).—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Philadelphia 44, Pa.*





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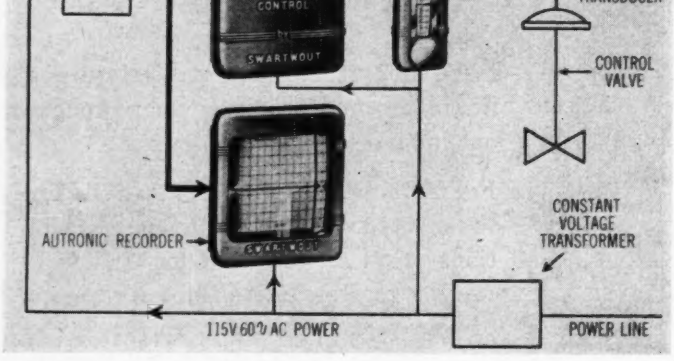
Electronic Control System



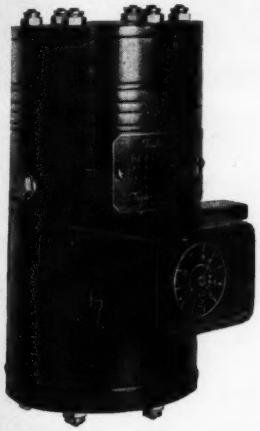
New "Autronic" control system is centralized-control miniature all-electronic system for measuring and controlling process variables such as temperature, pressure, level, flow, etc. System consists of three basic units—primary sensing element, "Autronic" control unit, and final control element. Power is 115-v. 60-cycle a.c. Control unit incorporates proportional band, reset, and rate time (derivative). Furnished with or without set-point adjustment and scale. Recorder permits inspection of record without interruption of pen track; holds month's supply of paper. Manual controller permits switching from automatic to manual control. Valve position is shown at all times, whether operating on manual or automatic.—*The Swartwout Co., 18511 Euclid Ave., Cleveland 12, Ohio.*

Mention No. 1103 when filling out card.

Process Controller

New "Transet Bi-Act" force-balance controller has only one-knob adjustment for two control responses. Controller is designed for applications where the

measured variable is transmitted to some remote location, where fast reset rates and broad throttling bands are required or where derivative action is not essential. Features include (1) control circuit which pneumatically links proportional and automatic reset responses, (2) one knob to adjust both

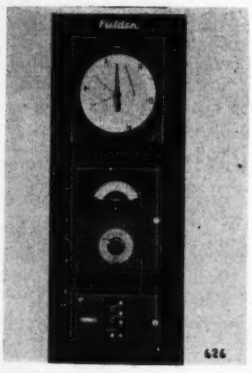


proportional and automatic reset responses, (3) controller action can be changed without disturbing any piping connections, (4) optional plug-in type leakless manifold provides means for connecting or removing controller, (5) rapid controller action obtained by large-capacity booster air relay, and (6) built-in cut-off relay provided for panel or field mounting. Controller measures only 7½-in. over-all length and has a range of adjustment of 1 to 200 percent throttling range and automatic-reset adjustment of 0 to 100 repeats per minute.—*Taylor Instrument Companies, Rochester 1, N. Y.*

Mention No. 1105 when filling out card.

Proportional Step-by-step Control

New "ARC-1 Automatic Control" indicates and records process variable and automatically corrects for deviation from control point. Control can



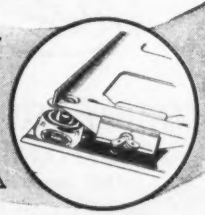
ignore momentary deviations, then make corrections at time intervals automatically adjusted to process speed. Push buttons for manual control are provided. Pilot lights indicate when variable is within tolerance limits,

Vibration isolation and shock protection for Airborne Equipment

● For the first time, dependable MET-L-FLEX all-metal mounts are available for many different applications requiring #1 cup type units. New standards of equipment performance, previously unattainable with conventional mounts, can be obtained without sacrificing weight or cost. High damping and axial-lateral stability, inherent features of MET-L-FLEX, provide added protection for delicate avionic equipment. Write today for full performance and engineering data on the complete line of Robinson MET-L-FLEX vibration isolation and control systems.

- **Load ranges from ½ lb. to 10 lbs. per mount.**
- **Built-in damping with auxiliary cushioning for overload and shock.**
- **Overload and underload capacity as great as 50%.**
- **Minimum ultimate structural strength 700 lbs. per unit.**
- **Temperature range −90°C to +175°C.**

Available in complete Unit Mount Bases including the popular S-1 and S-2 mounting tray sizes. Write today for information.



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Vibration Control Engineers

Century

RECORDING GALVANOMETERS

The Century Model 210 Galvanometer has been designed and tested for the utmost in performance under any conditions. The unique small tubular type construction permits their installation in practically any type or make of photographic recording oscillographs. These galvanometers are offered at low cost over a wide range of frequencies and sensitivities to satisfy most recording requirements. For additional information, write for our Catalog No. CGC 206.

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World's Largest Manufacturer of Geophysical and Special Galvanometers

above or below control point, or a correction is being made.—*Fielden Instrument Corp.*, 2920 *N. Fourth St. Philadelphia* 33, *Penna.*

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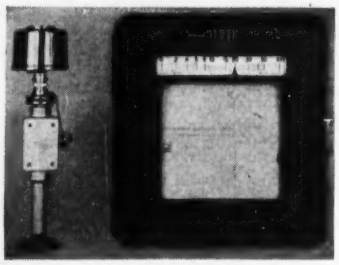
Daylight Illuminometer

New daylight illuminometer, consisting of "Speedomax" recorder and special illuminometer cell assembly, records daylight intensity directly in foot-

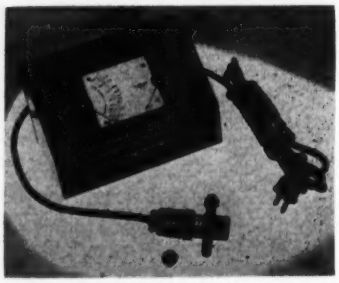


candles. Logarithmic scale is for maximum detail of record. Cell is barrier-layer photocell designed for collecting total illumination of sun and sky, and for filtration to match photocell spectral response to mean visibility curve of human eye. Cell may be several hundred feet from recorder.—*Leeds & Northrup Co.*, 4934 *Stenton Ave., Philadelphia* 44, *Penna.*

Mention No. 1107 when filling out card.

Electronic Manometer and Flowmeter

New "Electronic Manometer and Flowmeter" has noble-metal thermopile. Two taps on gage tube connect to two points at which pressure difference is measured. As flowmeter, tube

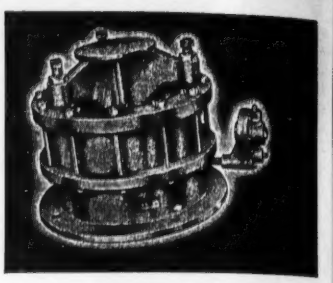


is placed directly in line or connected to two sides of calibrated orifice. Manometer measures low pressure differences; has dual range of 0.001 to 0.1 in. and 0.1 to 2 in. water. Accessories include 5-position switching attachment. Operates on 110-v. 60-cycle a.c.—*Hastings Instrument Co., Inc., Super Highway and Pine Ave., Hampton* 10, *Va.*

Mention No. 1108 when filling out card.

Pneumatic Weight Transmitter

New "F-C Air-Scale Weight Transmitter" converts force or weight into a pneumatic signal. Operates on force-balance principle. Accuracy of weight

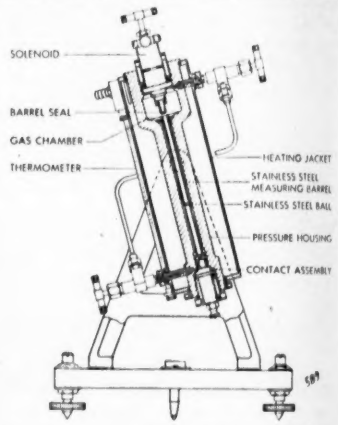


output is limited only by characteristics of indicating instruments used. Total movement is restricted to ⅛ in., protecting components from mechanical damage. Unit capable of weighing up to 10,000 pounds occupies less than one cubic foot of space. Sizes available weigh up to 40 tons directly (higher on special order).—*Fluid Controls Co., Inc.*, 5150 *Ridge Ave., Philadelphia* 28, *Penna.*

Mention No. 1109 when filling out card.

Oil-field Viscosimeter

New viscosimeter is rolling-ball type unit for viscosity at pressures and temperatures up to 10,000 psi. and 350 F. Roll time of ball is automatically measured by electric stop clock. Meas-

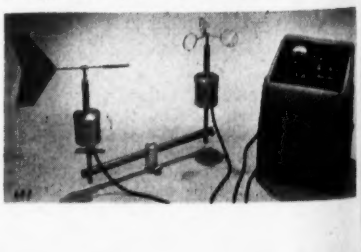


uring barrel of stainless tubing is honed to mirror finish, following which free-fitting ball is inserted. Seal closes ends of barrel while viscosity measurements are made.—*Ruska Instrument Corp.*, 4607 *Montrose Blvd., Houston, Texas.*

Mention No. 1110 when filling out card.

Climate-survey System

New system uses drag-free anemometer and electronic techniques to record wind direction and wind speeds from below 1 mph. to 30 mph. Unit is energized by own battery supply and weighs 100 lbs.—with batteries. Speed

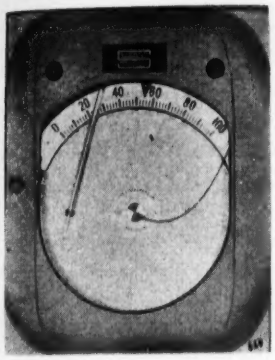


and direction recordings are made on separate standard 0-1 milliammeters (not supplied in standard system).—*Beckman & Whitley, Inc., 930 San Carlos Ave., San Carlos, Calif.*

Mention No. 1111 when filling out card.

Smoke Density Recorder

New "SR-6L Smoke Indicator-Recorder" is quick-acting sensitive null-balance potentiometer. Has rugged

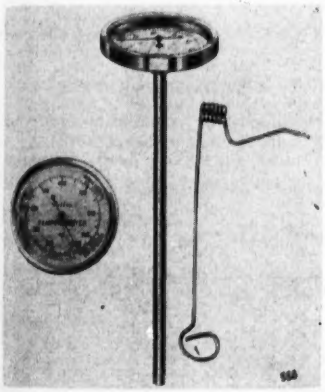


steel case, large pointer indicator, fluorescent illumination, and 12-in. chart for 24-hour record. Warning signals at any limits may be added.—*Ess Instrument Co., 96 S. Washington Ave., Bergenfield, N. J.*

Mention No. 1112 when filling out card.

Bimetallic Thermometers

New model of maker's "Temperometer" is for checking temperatures of molten lead, solder, Babbitt metal, oils,



waxes, etc. Chief improvements are: head and stem of stainless steel; stem diam. of 9/32 in.; and tube end positively closed.—*W. C. Dillon & Co., Inc., 1421 S. Circle Ave., Forest Park, Ill.*

Mention No. 1113 when filling out card.

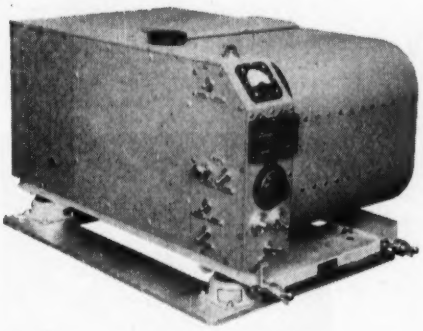
Marine Autopilot

New automatic marine pilot system follows any course received from human or automatic source. Whereas a helmsman might overcontrol rudder in wind and swells, autopilot follows course with variation of less than one-half degree. Makers claim "almost complete

Century INDUSTRIAL

RECORDING OSCILLOGRAPH

FOR VIBRATION, TEMPERATURE, STRESS, STRAIN ANALYSIS



MODEL 408 OSCILLOGRAPH

The Century Model 408 recording oscillograph was designed expressly for airborne and mobile operation. As with all Century products, this oscillograph incorporates the utmost in design and workmanship, along with improved features, yet it remains simple in its operation and maintenance.

FEATURES:

Size: 20" long, 12½" wide, 8⅞" high.

Weight: 60 pounds.

Number of Recording Channels: 6 to 50.

Detachable daylight loading magazine accommodating a roll of paper or film 8" x 200'.

Friction roller type paper drive by governor controlled electric motor with separate motor for takeup drive.

Paper speeds continuously and instantly variable without changing gears or sprockets.

Separate optical system for viewing before or during recording.

Glow tube timing system photographing .01 second and .1 second lines. .01 second lines instantly removable by toggle switch for slower speeds.

Data numbering at beginning of record.

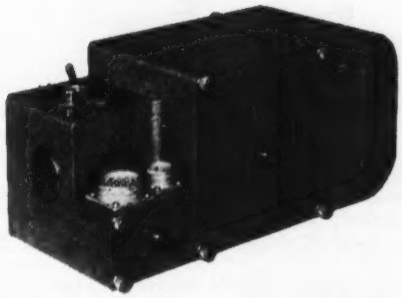
Footage indicator showing amount of paper remaining in magazine.

Automatic record length control.

Trace identification.

Remote control unit.

MODEL 409 OSCILLOGRAPH



The Century Model 409 oscillograph has been designed for recording data where space and weight requirements are limited. This oscillograph has been tested to record faithfully while subjected to accelerations up to 20 G's.

FEATURES:

Size: 5" x 5" x 11".

Weight: 11 pounds.

Cast Aluminum case.

Paper speeds variable ½" to 12" per second.

Detachable daylight loading magazine with a capacity of 3⅝" x 50' paper or film.

2 to 12 individual channels.

Trace identification.

Trace viewing.

For Complete Information Write 1340 North Utica

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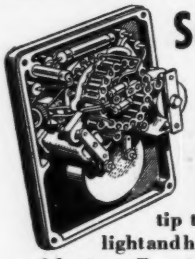
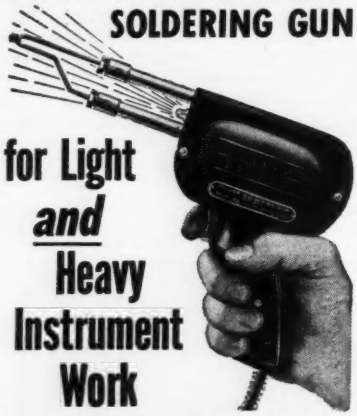
Adjust Heat INSTANTLY for ALL TYPES of Soldering



Controlled dual heat—on in 5 seconds, off when you release trigger—lets you adjust tip temperature for light and heavy instrument soldering. Precision balance, longer reach and tip construction ideal for delicate jobs. Rating up to 250 watts speeds heavy work. Time-and-power savings pay for your Weller Gun in a few months.

250-Watt WELLER SOLDERING GUN for Light *and* Heavy Instrument Work



- **TRIGGER-SWITCH CONTROL**—Ideal for intermittent work. No need to unplug gun between jobs.
- **5-SECOND HEATING**—No waiting, no wasted current.
- **PRECISION BALANCE**—Simplifies delicate work.
- **SOLDERLITE**—Spotlights the work.
- **LONGER REACH**—Slides easily into tight spots.
- **WELLERTIP**—Chisel shaped for faster heat transfer. Over/under terminals brace tip for heavy duty.
- **DUAL HEAT**—Single heat 200 watts; dual heat 200/250 watts; 120 volts, 60 cycles. For all instrument soldering.

See the 250-watt Weller Soldering Gun at your distributor, or write for bulletin direct.

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WELLER ELECTRIC CORP.
800 Packer Street, Easton, Pa.

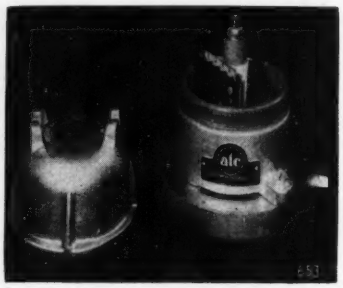
NEW INSTRUMENTS

lack of maintenance" because of use of magnetic amplifiers.—*General Electric Co., Schenectady 5, N. Y.*

Mention No. 1114 when filling out card.

Pressure Transmitter

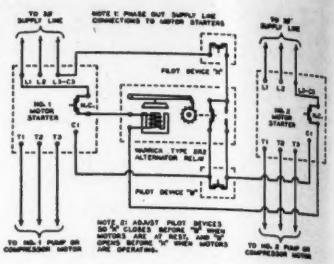
New explosion-proof diaphragm differential-pressure transmitter determines level of catalyst in tanks, bins, drums, etc. Linear-transducer measuring system provides remote visual signal. Transmitters, with range of 0-600 psi. maximum static pressure, can trip indicating relay with 1-in. water differential-pressure change, and are connected to Thyratron relay. Relay operates indicator light on panel.—*Automatic Temperature Control Co., Inc.*, 5200 *Pulaski Ave., Philadelphia 44, Penna.*



Mention No. 1115 when filling out card.

Alternator Relay

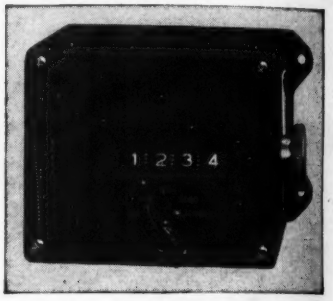
New "Type 2R2" relay maintains alternate operation of twin pumps or compressors which use float or pressure switches in driving-motor circuits. When one unit is unable to meet demand, second unit assists first until normal shut-off level or pressure is reached. Available open or enclosed with ¼-in. silver contacts. Each motor starter requires auxiliary normally-closed contact element in series with alternator relay coil.—*Charles F. Warrick Co.*, 1964 *W. 11-Mile Rd., Berkley, Mich.*



Mention No. 1116 when filling out card.

Automatic Batch Counters

New "Type WA Electric Batch Counter" automatically closes switch to control signals, conveyors, packaging equipment, etc. Can be furnished to count various quantities or combination of quantities. Four number wheels register units counted until reset. Counting speeds to 600 C.P.M.—*Production Instrument Co.*, 702 *W. Jackson Blvd., Chicago 6, Ill.*

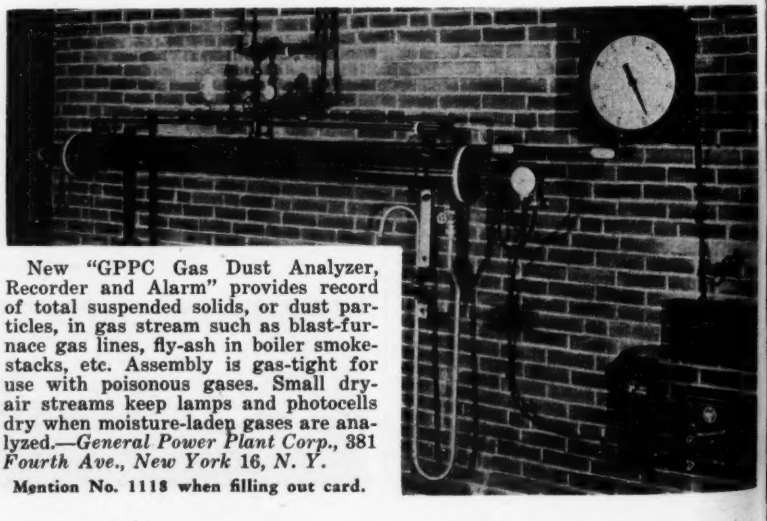


Mention No. 1117 when filling out card.

Engine Analyzer

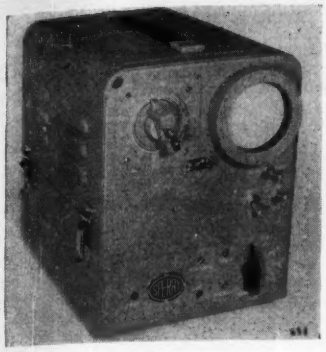
New airborne electronic engine analyzer uses cathode-ray trouble-shooter technique to reveal internal working

Gas Analyzer and Alarm



New "GPPC Gas Dust Analyzer, Recorder and Alarm" provides record of total suspended solids, or dust particles, in gas stream such as blast-furnace gas lines, fly-ash in boiler smokestacks, etc. Assembly is gas-tight for use with poisonous gases. Small dry-air streams keep lamps and photocells dry when moisture-laden gases are analyzed.—*General Power Plant Corp.*, 381 *Fourth Ave., New York 16, N. Y.*

Mention No. 1118 when filling out card.

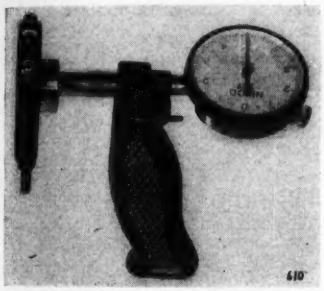


conditions of engines during flight, including timing variations in each valve, engine crankshaft's position at any instant during rotation, and output torque of engine during flight. Operates on 50-500 cps. power. Weight is 27 lbs.—*Sperry Gyroscope Co., Great Neck, N. Y.*

Mention No. 1119 when filling out card.

Bore Gage

New "Nilco Pistol-Type Bore Gage" checks bores where space is limited. Indicators face operator at all times.

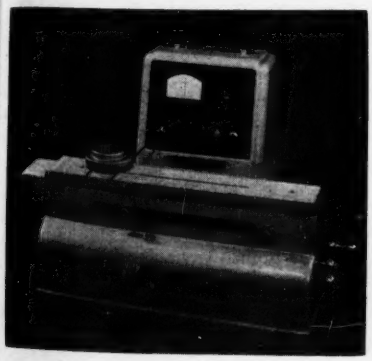


Gage has three-point alignment, two-point gaging feature, and one-piece centralizing plungers. Any indicator can be adapted to gage.—*Nilsson Gage Co., Inc., Poughkeepsie, N. Y.*

Mention No. 1120 when filling out card.

Electronic Gaging Head

New remote electronic gaging head for "N-6 Internalchek" has standard dual amplifications of 1,000/2,000, 300/3,000, 5,000/10,000 to 1; others on special order. Gage head consists of stable vacuum-tube circuit and high-



Check THESE 7 ADVANTAGES

OF SANBORN DIRECT WRITING RECORDING SYSTEMS

1 COMPLETE SYSTEM or SEPARATE COMPONENTS
Sanborn equipment is available as complete 1-, 2-, or 4-channel systems *ready for use*, or as separate instruments (Amplifiers, Preamplifiers, and Recorders), to be combined or integrated by the user with other equipment.

2 NO INK
Permanent records are produced with heated stylus on heat responsive, continuous plastic coated chart paper. Elimination of ink permits, among many advantages, use of the recorder in any position, at any angle, and at high altitudes.

3 RECTILINEAR RECORDS
Records are in true rectangular coordinates (with *negligible* tangent error), permitting more accurate correlation when two or more channels are used simultaneously.

4 HIGH TORQUE MOVEMENT
The writing arm is driven by a D'Arsonval moving coil galvanometer with an extremely high torque movement (200,000 dyne cms per cm deflection). Sensitivity 10 m.a./cm deflection.

5 WIDE CHOICE OF PAPER SPEEDS AND RECORDING CHANNELS
Basic choice of 1-, 2-, or 4-channel models. Single channel standard speed 25 mm/sec., slower speeds available. Two channels, 10 speeds — 5 and 0.5, 10 and 1, 25 and 2.5, 50 and 5, 100 and 10 mm/sec. Four channel, eight speeds — 50, 25, 10, 5, 2.5, 1.0, 0.5, and 0.25 mm/sec.

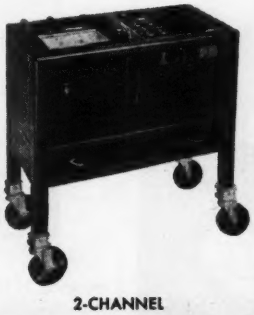
6 CODE & TIME MARKINGS
All models provide a means of inserting timing pips in the record once each second independently of the paper drive, and code markings at will.

7 INTERCHANGEABILITY
Ready interchangeability of Amplifiers and Preamplifiers in all Sanborn systems permits a wide variety of recording combinations.

WRITE FOR COMPLETE CATALOG

If your problem involves recording any phenomena (individually, or simultaneous recording of up to four) that can be expressed electrically, you will find Sanborn equipment ideally suited to your requirements.

1-CHANNEL



2-CHANNEL

4-CHANNEL

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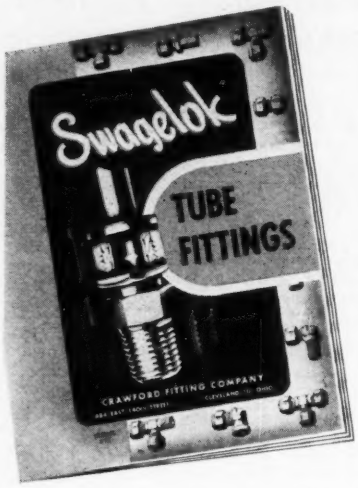

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Every instrument man, process piping man, designer, engineer, and purchasing agent should have this new Swagelok Tube Fittings Catalog. It gives you at a glance, detailed, illustrated data on the complete line of Swagelok tube fittings in brass, aluminum, steel, stainless steel, and Monel. It's your complete guide to economical, torque-free, leakproof joints in all instrumentation and process piping lines.

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COME TO YOU COMPLETELY ASSEMBLED, FINGER TIGHT

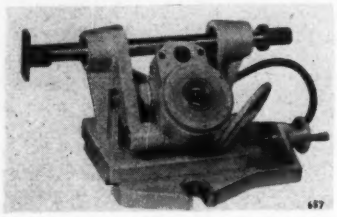
NEW INSTRUMENTS

speed meter. Regulating transformer eliminates drift. Gaging range is from 0.370-in. to 12-in. dia. Maximum gaging depth from surface plate to center of diamond point is 1.5 in.—*The Sheffield Corp., Dayton 1, Ohio.*

Mention No. 1121 when filling out card.

Optical Cam Rise Gage

New "Cam Rise Gage" measures cam contours (angle and eccentricity) by optical means. Deviation can be measured to ten thousandths of an inch.



No focusing necessary. For angular measurements, gage is used with dividing head and tail stock. Linear scale is graduated from 0 to 3 inches in 50 thousandths of an inch. Direct readings can be made to 0.0005 in.—*F. T. Griswold Mfg. Co., Wayne, Pa.*

Mention No. 1122 when filling out card.

Universal Depth Gage

New "Model DG-56-R-1" has reference platen 3.25 in. wide and 4 in. long. Measuring range is 1 in. (0-1 in. or 1-2 in.) plus indicator range. Instrument uses any AGD indicator with AGD adjustable-bracket back, 2.25-in. diam. dial. Seven English and Metric indicator ranges are available.—*Saart, Kraemer & Hanscom, Inc., 1 Washington Ave., Providence 5, R.I.*

Mention No. 1123 when filling out card.

Lens

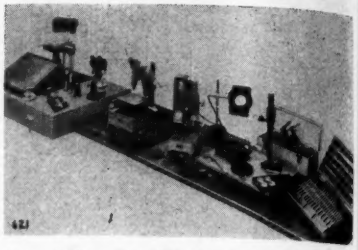
New "Floodlight Model" lens for inspection and assembly has 12-in. field. 400 foot candles developed from light

source. Incorporates color filters for relief of eye fatigue. Base brackets are adjustable. Available in focal lengths of 4, 6, and 12 in.— *The McMahill Colorama Co., 3618 Superior Ave., Cleveland 14, Ohio.*

Mention No. 1124 when filling out card.

Inspection Laboratory

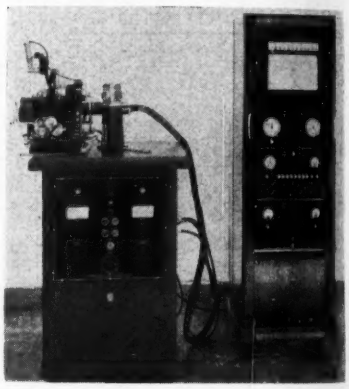
New "Limited Budget Laboratory" contains instruments needed to meet government specification "MIL Q 5923," issued Dec. 8, 1950, for inspection, testing, and production tooling. Instruments, which can be purchased separately, include a micro-projector, microscopes, magnifiers, height gages, gage blocks, micrometers, etc.—*Geo. Scherr Co., Inc., 200 Lafayette St., New York 12, N. Y.*



Mention No. 1125 when filling out card.

Fluorescence Analysis Unit

New "Norelco Fluorescence Analysis Unit" is for rapid qualitative and quantitative analysis of metals, minerals, chemical mixtures, etc. Specimens are exposed to beam of X-radiation which



excites elements. Radiations then are passed through a collimating system to a crystal which reflects individual radiations at a specific angle. Intensities are measured by Geiger counter on goniometer with sweep radius of 170 mm. Electronic circuits drive strip-chart recorder or count register.—*Research & Control Instruments Div., North American Philips Co., Inc., 750 S. Fulton Ave., Mt. Vernon, N. Y.*

Mention No. 1126 when filling out card.

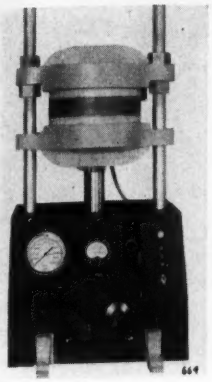
Ball-bearing Microscopes

New "Dynoptic Labroscopes" are laboratory microscopes with ball bearings and rollers for effortless high-precision focusing. Pressure-loaded ball bearings around rim of nosepiece are said to afford "unequalled smoothness and precision of movement." Other features: optically improved 16-mm. objective, sliding variable-focus condenser, and attachable integral illuminator.—*Bausch & Lomb Optical Co., 635 St. Paul St., Rochester 2, N. Y.*

Mention No. 1127 when filling out card.

Hydraulic Press

New "Model 30-11" hydraulic laboratory press provides total force of 60,000 lbs. Gage indicates psi. on ram. Stroke is 6 in.; max. opening is 20 in.



Platens of 11-in. dia. are heated electrically and controlled by bimetallic regulator. Temperature in deg. F. indicated on millivoltmeter.—*Hydraulics Div., Wabash Metal Products Co.*, 1569 *Morris St., Wabash, Ind.*

Mention No. 1128 when filling out card.

Tensile Tester Accessories

New compressional accessories for tensile tester include auxiliary removable crosshead. Compression-type load cells are on rigid table. Load deformation, cyclic, and relaxation tests can be made on compression and tension. Full-scale range with 3 interchangeable load cells are from 20 grams to 5000 lbs. Auxiliary integrator can integrate area under load-deformation curve.—*Instron Engineering Corp., 2 Hancock St., Quincy 71, Mass.*

Mention No. 1129 when filling out card.

Quartz Orientation Unit

New improved quartz orientation unit has new optics and precision gearing. Tolerances in quartz orientation can be held to one minute. Goniometer radius is 150 mm., angular range is from 0 to plus 90 deg., and scanning range is 10 deg. on either side of chosen Bragg angle. Angles can be read to ½ min. arc. Features include high-capacity generator which operates on 200-240 v., 50 or 60 cycle, single-phase a.c., built-in stabilizer, and air-cooled X-

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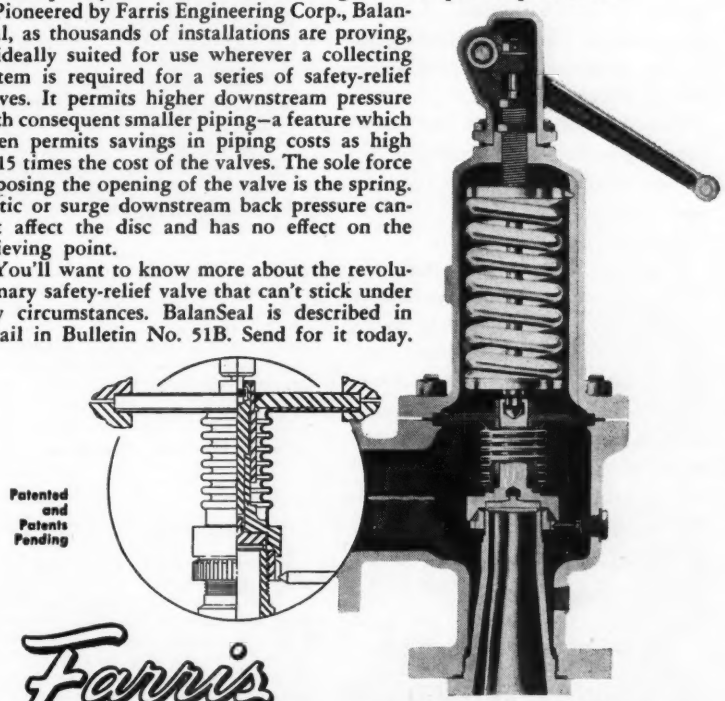
A safety valve that sticks is about as safe as a time bomb

Only BalanSeal© and FarriSeal© provide the positive protection at all times and under all operation conditions that makes them reliably safe.

Unique in design and principle, the BalanSeal Safety-Relief Valve has a protective bellows which is proportioned to eliminate any unbalanced downstream forces on the valve disc—which is perfectly balanced on its seat at the set pressure. Like its companion, the FarriSeal Valve, the guide, stem and spring are completely isolated from the lading fluid for perfect protection.

Pioneered by Farris Engineering Corp., BalanSeal, as thousands of installations are proving, is ideally suited for use wherever a collecting system is required for a series of safety-relief valves. It permits higher downstream pressure with consequent smaller piping—a feature which often permits savings in piping costs as high as 15 times the cost of the valves. The sole force opposing the opening of the valve is the spring. Static or surge downstream back pressure cannot affect the disc and has no effect on the relieving point.

You'll want to know more about the revolutionary safety-relief valve that can't stick under any circumstances. BalanSeal is described in detail in Bulletin No. 51B. Send for it today.



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Farris

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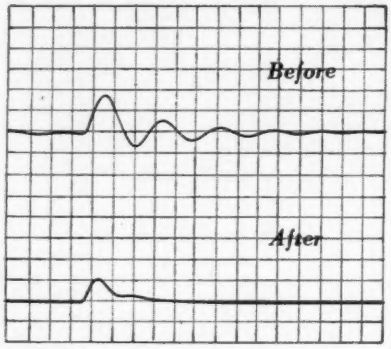
Engrg.

and Research Programs may be greatly *abbreviated* by a Philbrick Analog Computor of the high-speed all-electronic variety.

Dollars and days in surprising numbers have been saved by enterprising engrs. who have recognised the applicability of these little machines to their development probs.



How do we stabilize this structure or system? What is the optimum combination of these parameters? Why cannot this process be accelerated without sacrifice in efficiency? —

Questions of this sort and many others are answered regularly by analog systems assembled directly and conveniently from GAP/R Computor Components.

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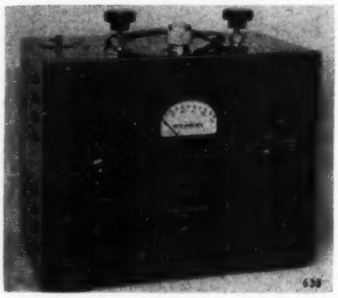
NEW INSTRUMENTS

ray tube. Equipment is available with one or two goniometers and rate-meter circuits. Geiger counter has high sensitivity and long life. Characteristics include short resolving time, stable reproducible functions, and rate-meter indications. Weight of single unit is 250 lbs.—*Research & Control Instruments Div., North American Philips Co., Inc., 750 S. Fulton Ave., Mt. Vernon, N. Y.*

Mention No. 1130 when filling out card.

Vacuum Leak Locator

New "Type EMV-7" hydrogen-sensitive ionization-type leak locator weighs only 31 pounds. Vacuum system can be pumped down within two minutes. Can detect leaks as small as 1×10^{-5} liter-



microns of hydrogen per second. Heart of leak locator is sealed-off high-vacuum gage tube "RCA type 1945," which responds only to hydrogen. Instrument has stable d-c. amplifier, microammeter, and self-contained power supply. Operates from 110-v. 60-cycle line—*Scientific Instrument Section, Radio Corp. of America, Camden, N. J.*

Mention No. 1131 when filling out card.

Laboratory Hot-plate

New heavy-duty laboratory hot plate with graduated "Chromatrol" heat control permits infinite variability of first 50-percent of total wattage of unit. By selecting models rated between 660 and 200 watts, any desired surface temperature up to 800 deg. F. can be maintained. Operate on 120 or 240 v. a.c. Design incorporates totally enclosed resistor wires and coolness of handling.—*Edwin L. Wiegand Co., 7568 Thomas Blvd., Pittsburgh 8, Penna.*

Mention No. 1132 when filling out card.

Controlled Water Bath

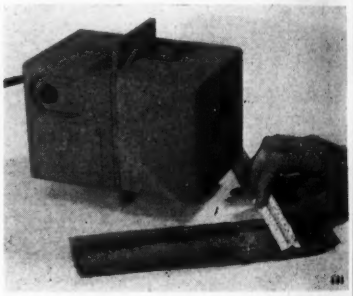
New "Isotemp Bath" maintains constant bath temperature within 0.005 deg. C. over range from minus 5 to plus 107 deg. C. Electronic circuit con-

trols 400-watt and 800-watt heaters. Unobstructed top surface for inserting samples. Motor stirring keeps entire 10-gallon content constantly in motion. Accessory cooling coil available.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.*

Mention No. 1133 when filling out card.

9-Channel Oscillograph

New "Type 5-118" oscillograph records nine sources of data, yet is only 5 x 5 x 8 in. Operates from 28-v. d-c.

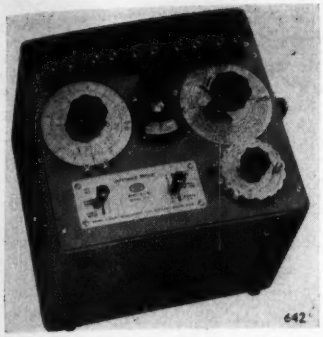


power source. Standard "Type 7-200" galvanometers are easily adjustable or replaceable when film magazine is removed. Translucent cover hinges to become graduated screen for vertical and horizontal adjustment of light spots.—*Consolidated Engineering Corp., 300 N. Sierra Madre Villa, Pasadena 8, Calif.*

Mention No. 1134 when filling out card.

Impedance Bridge

New "Model 250-C" universal impedance bridge has following ranges: Resistance—1 milliohm to 11 megohms; capacitance.—1 uuf. to 1100 uf.; inductance—1 uH. to 1100 H.; dissipation factor ($D = R/X = R\omega C$)—0.001 to 1.0; storage factor ($Q = X/R = \omega L/R$)—0.02 to 1000. Internal bridge oscillator is 1000-cps. microphone hummer. Galvanometer is used for resistance measurement; terminals for headphones or auxiliary "Model 855-A amplifier-oscillator" are used for a-c. null-detection measurement of L and C. Power is four

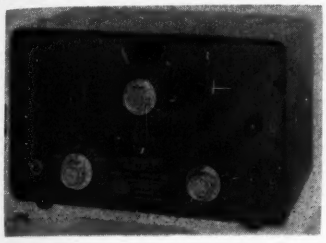


"D" flashlight cells, or external battery or oscillator.—*Dep't I-3, Brown Electro-Measurement Corp., 4635 S. E. Hawthorne Blvd., Portland 15, Oregon.*

Mention No. 1135 when filling out card.

Low-frequency Oscillator

New "Model 420-A" low-frequency oscillator simultaneously provides sine and square-wave voltages at any frequency between 0.35 and 52,000 cps.



Features include low distortion and hum, calibrated output-level control, amplitude constancy over entire frequency range, fast AVC action, vernier tuning control, and single-scale logarithmic dial.—*Krohn-Hite Instrument Co., 580 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 1136 when filling out card.

Regulated Power Supply

New "Model 1020" regulated high-voltage power supply has low ripple content and low output impedance.

Supply is variable from 0 to 1000 v. and delivers from 0 to 50 ma. A 6.3-volt 10-ampere a-c. supply is included. Weight is 66 lbs.—*Kepco Laboratories, Inc., 149-14 41st Ave., Flushing, N. Y.*

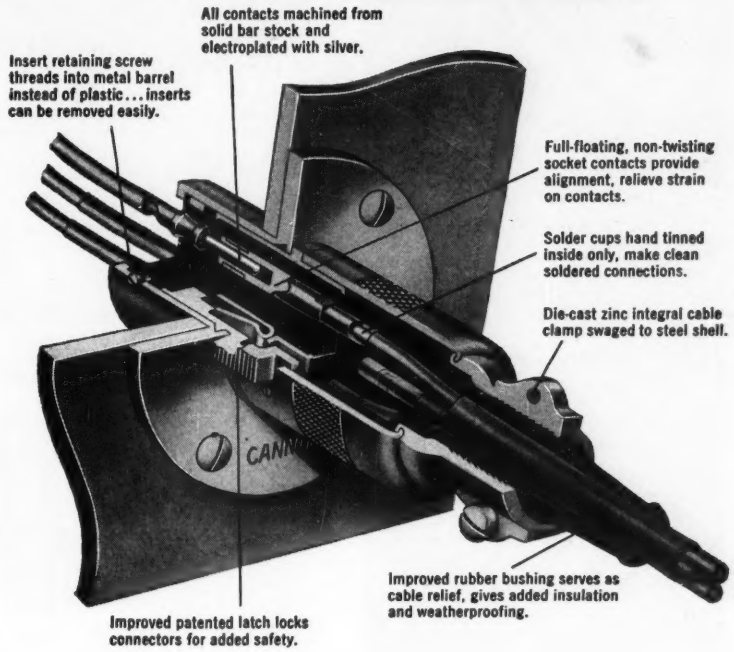
Mention No. 1137 when filling out card.

Power Supply

New "Model N" supply provides a continuously variable source of filtered d-c. power (0-28 volts at 15 amp.) for operating and testing electronic equip-

Here's why those in the know —demand

CANNON PLUGS

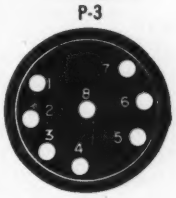

All contacts machined from solid bar stock and electroplated with silver.
Insert retaining screw threads into metal barrel instead of plastic... inserts can be removed easily.
Full-floating, non-twisting socket contacts provide alignment, relieve strain on contacts.
Solder cups hand tinned inside only, make clean soldered connections.
Die-cast zinc integral cable clamp swaged to steel shell.
Improved rubber bushing serves as cable relief, gives added insulation and weatherproofing.
Improved patented latch locks connectors for added safety.

If you talk to sound technicians anywhere you'll find Cannon Type P connectors are the accepted standard of quality... taking a beating day in day out where frequent changes in circuits are required on all kinds of jobs up to 30 amp. capacity.

The close attention to important details called out in the above illustration is typical of the care used in the design and construction of all Cannon Plugs—the world's most complete line.

The above type series is distributed through selected franchise distributors. The line is fully described in the Type P Bulletin. Engineering bulletins describing each of the many basic types of Cannon Plugs will be sent on request.

P-3



P-8

Type P insert arrangements include 2-3-4-5-6 and 8 contacts. All contacts are 30 amp. capacity except those in P-8 layout which are 15 amp. Full scale layouts, front view pin insert, engaging side, shown at right.

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Meets AN Specifications
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Single pole and double pole
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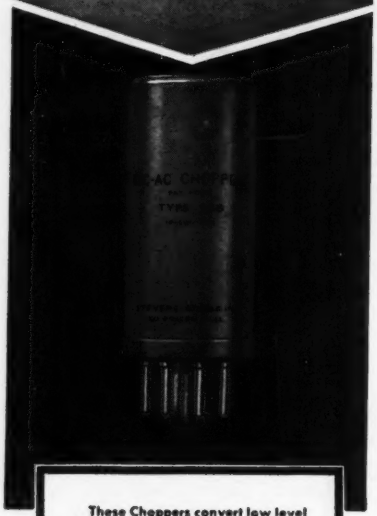
Contacts in air or in liquid



These Choppers convert low level DC into pulsating DC or AC so that servo-mechanism error voltages and the output of thermocouples and strain gauges, may be amplified by means of an AC rather than a DC amplifier.
They are hermetically sealed, precision vibrators having special features which contribute to long life and low noise level.

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#280 10-500 cycles
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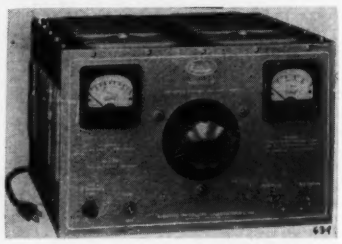
NEW INSTRUMENTS



ment, relays, plating operations, etc. Uses bridged selenium rectifiers. Voltmeter and ammeter are accurate to 2 percent. Operates from 110-v. 60-cycle source.—*Electro Products Laboratories, Inc.*, 4501 *N. Ravenswood Ave., Chicago* 40, *Ill.*

Mention No. 1138 when filling out card.

Pulse Generator

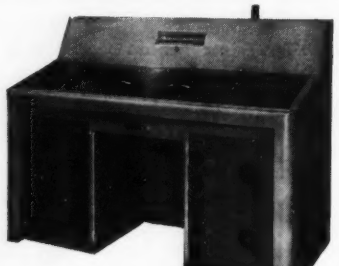
New "Rada-Pulser" pulsed carrier generator is useful in transient-response analysis. Carrier frequencies are 30 and 60 Mc. Pulse widths are

0.1 and 0.25 microsecond. Pulse repetition rate is variable from 500 to 2000 pps. Maximum r-f. output is 1 volt at 70 ohms. Pulse output is 50 volts at 70 ohms. Positive and negative trigger pulses are furnished ahead of pulsed carrier to trigger oscilloscope sweep circuit.—*Kay Electric Co., Pine Brook, N. J.*

Mention No. 1139 when filling out card.

Magnetic Testing Desk

New d-c. magnetic testing desk contains all equipment necessary for d-c. magnetization and hysteresis tests and flux measurements. Nearly all mag-

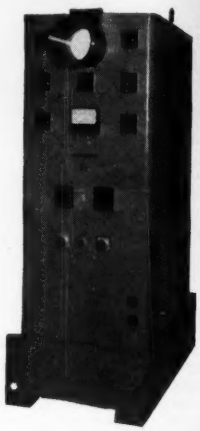


netic materials can be tested. Sloping top places all controls within easy reach of operator. Weight is 600 lbs. Current is adjustable from zero to 40 amps. Operates on 125-v. d.c. and 115-v. 60-cycle a.c.—*Special Products Div., General Electric Co., Schenectady* 5, *N. Y.*

Mention No. 1140 when filling out card.

Winding-insulation Tester

New d-c. winding-insulation tester for d-c. armatures, series field coils, and low-impedance a-c. stator coils consists of surge-voltage generator and cathode-ray oscilloscope. Test voltage is applied to commutator of armature being



tested. Surge generator consists of 0.5-uf. capacitor which is charged in one half-cycle and discharged in next half-cycle. Voltage is adjustable to 7500-v. peak. Discharge is through Ignitron rectifiers. Standing wave, shown on oscilloscope screen, indicates if surge wave is of proper shape and amplitude. Weight is 800 lbs. Operates on 230-v. 60-cycle supply.—*Special Products Div., General Electric Co., Schenectady* 5, *N. Y.*

Mention No. 1141 when filling out card.

High-current Tester

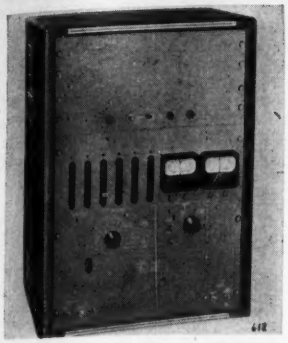
New "Model 1002 Multi-Amp," for testing and calibrating current-actuated devices, supplies any current from 0 to 500 amp. to device connected to

output terminals. Furnished for either 110- or 220-volt 60-cycle operation. Maximum output of 1200 amp. may be used for short periods. Equipped with 4-range 4-in. ammeter, circuit breaker, and fuse.—*Multi-Amp Corp.*, 121 *Cross St., Harrison, N. J.*

Mention No. 1142 when filling out card.

Frequency Counter

New "Model 524A" frequency counter measures frequencies from a few cps. to 10 Mc. For frequencies above 300 cps., instrument counts cycles in a fixed counting period and displays count (frequency) on digital indicator. For low frequencies, duration of a cycle



in a 10-cycle sample is indicated. Circuits include crystal-oscillator-controlled gate generator, which develops accurate counting interval, and pulse-counting circuits.—*Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.*

Mention No. 1143 when filling out card.

Single-sweep Accessory

New "Type 121" single-sweep accessory provides one pulse to trigger single sweep of a cathode-ray oscilloscope at start of any complex wave pattern,

and at no time thereafter. Output is a single negative output pulse from either a positive or negative input signal. Input required is 0.1 volt, and may be obtained from signal or external transducer. Operates from 110-v. 60-cycle supply.—*Sterling Instruments Co., 13331 Linwood Ave., Detroit 6, Mich.*

Mention No. 1144 when filling out card.

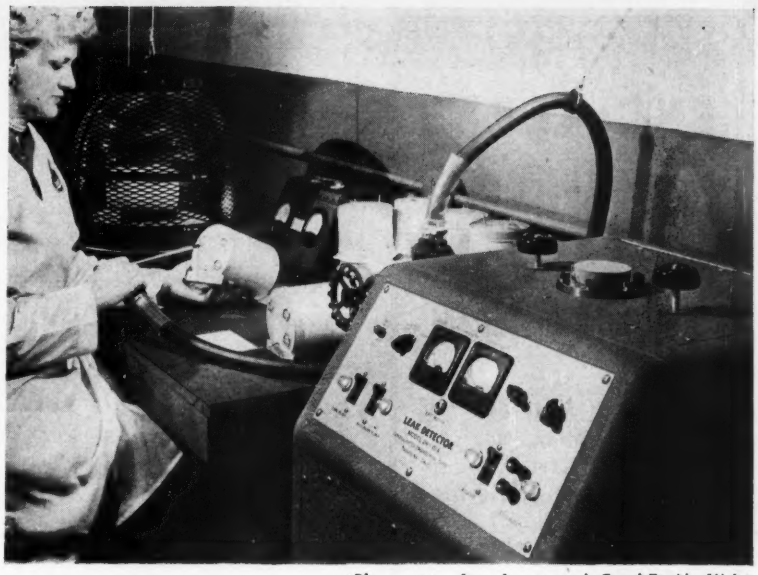
Xenon-filled Rectifier

New "RCA-3B28" xenon-filled half-wave rectifier tube is designed to perform under extreme ambient temperatures from minus 75 deg. to plus 90 deg. C. Rated at (1) peak inverse anode voltage of 10,000 volts and average anode current of 0.25 amp., or (2) peak inverse anode voltage of 5000 volts and average anode current of 0.5 amp. Voltage drop is 10 volts. Has medium-shell small 4-pin base with bayonet. Length is 6 in.—*RCA Tube Dep't, Harrison, N. J.*

Mention No. 1145 when filling out card.

Servo Motors

New low-inertia servo motors with high-voltage control windings eliminate transformers in servo amplifiers, there-



(Photo courtesy Lear, Incorporated, Grand Rapids, Mich.)

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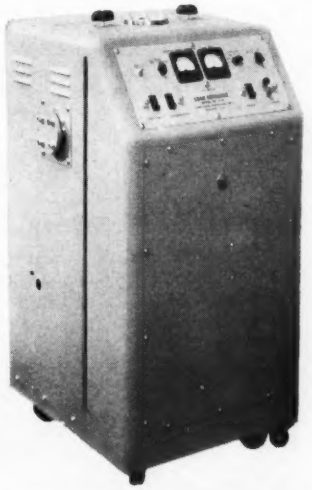
CONSOLIDATED ENGINEERING CORPORATION'S Leak Detector shows the existence or absence of any leak, the rate of leakage, and the exact location. Its almost unbelievable sensitivity will actually detect leakage at the rate of 1 c.c. in 31 years.

Above we see a corner of Lear, Incorporated's immaculate instrument products plant at Grand Rapids, Michigan. The operator is testing the hermetically sealed housings for gyro assemblies, components of the famous Lear Autopilot. The CEC Model 24-101A Leak Detector in use here is the only instrument sensitive enough for low-volume, low-pressure applications of this type.

In addition to this highly critical detecting operation, CEC's Leak Detector is ideal for industrial or laboratory vacuum equipment, high pressure cylinders, compressor units moving on an assembly line, glass-to-metal seals in electronic equipment, valves, welded and soldered joints, and many others.



Furnished as a complete, compact unit mounted on rubber casters. Standard equipment includes both visual and audible indicators.

For complete information on construction, operating principle and application of CEC Model 24-101A Leak Detector, request your copy of this profusely illustrated, 16-page bulletin CEC-1801-X32.

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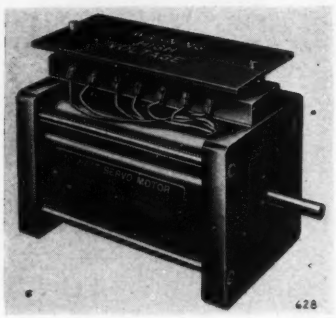
NEW INSTRUMENTS

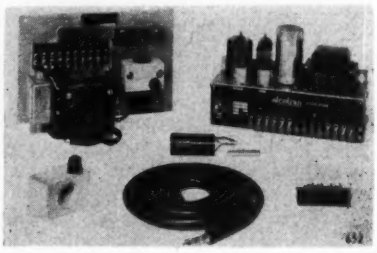


by saving weight and space. Available in 0.5, 1.5, 5, and 10 watt sizes, motors have close-coupled windings for feedback purposes.—*Ford Instrument Co., 31-10 Thomson Ave., Long Island City, N. Y.*

Mention No. 1146 when filling out card.

Servo Kit

New servo kit is servomechanism system which operates on linear-transformer principle and allows for measurement of straight-line motions such

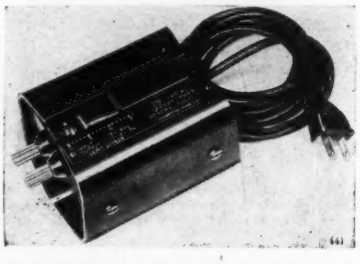


as displacement of diaphragm, etc. Kit contains differential transformer, standard servomechanism, amplifier, terminal block, mounting block, and cable. —*Automatic Temperature Control Co., Inc., 5200 Pulaski Ave., Philadelphia 44, Penna.*

Mention No. 1147 when filling out card.

Variable Transformer

New "Type 71-A Variac" transformer furnishes adjustable low-voltage 60-cycle power. Core withstands 1250-

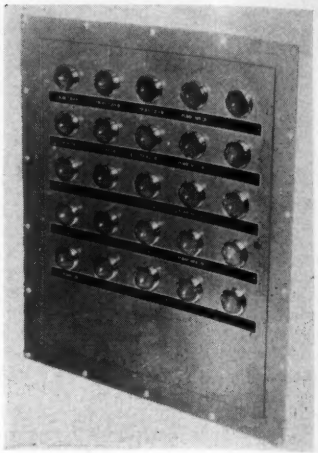


volt breakdown test. Continuous output current rating is 5 amperes with output voltage range from zero to 13 volts.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 1148 when filling out card.

Lamp Annunciators

New heavy-duty "Type Ann18 Annunciator" uses lamp units with 2-in. beehive lenses. Plug-in relays mount

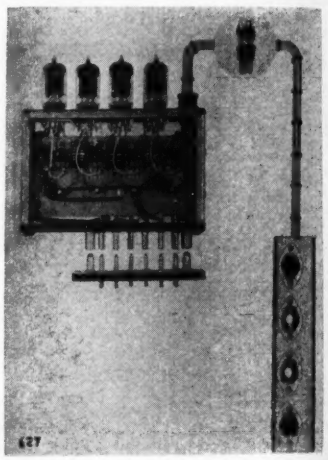


directly on rear of lamp units. For all voltages up to 250 v. a.c. or d.c. Available with 2-in. dia. flat lenses. Automatic service provides audible as well as visual signal.—*The H. R. Kirkland Co., Morristown, N. J.*

Mention No. 1149 when filling out card.

Counter Decades

New miniaturized four-tube "Electronic Counter Decade" is available in two models which differ only in maximum counting capabilities. "Model 12"



counts at rates to 130,000 counts per sec. "Model 13" counts at rates to 30,000 counts per sec. Features include four-lamp binary decimal indication arranged in 1-2-4-8 coding. Available with either remote panel-mounted four-lamp readout or small plug-in neon cluster.—*Potter Instrument Co., Inc., 115 Cutter Mill Rd., Great Neck, N. Y.*

Mention No. 1150 when filling out card.

Self-focusing C-r. Tube

New "Selfocus" cathode-ray tube requires no focusing controls or devices. Principle can be used in any size cath-

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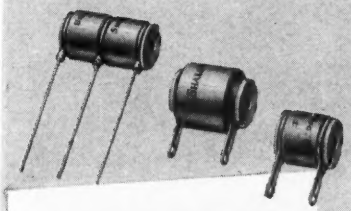

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For years, Shallcross has led the way in the production of truly dependable close-tolerance, high-stability resistors in miniature sizes. Standard and hermetically sealed types are available.

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Shallcross regularly produces hundreds of special precision resistor types including precision power resistors, resistors with axial or radial leads and multi-unit strip resistors (illustrated) with either inductive or non-inductive windings.

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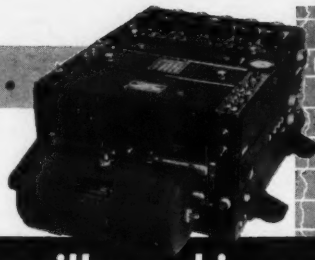

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FULL RESILIENT MOUNTING makes possible use of super-sensitive galvanometers

CHART TRAVEL INDICATOR provides continuous indication of chart motion

NEW GALVANOMETER STAGE takes all Hathaway galvanometers for recording milliamperes, microamperes, and watts.

NEW RECORD-LENGTH CONTROL and NUMBERING SYSTEM for long, trouble-free service

All the other valuable features characteristic of the S-8 are retained. Investigate the NEW Type S-8 and its 170 types of galvanometers.

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Newtown, Connecticut

ode-ray tube and is being incorporated in 17-, 20-, and 21-inch "Teletrons."—*Cathode-ray Tube Div., Allen B DuMont Laboratories, Inc.*, 750 *Bloomfield Ave., Clifton, N. J.*

Mention No. 1151 when filling out card.

Small Synchronous Motor

New small synchronous motor, operating on reluctance principle, has no brushes, slip rings, rotating coils, or permanent magnet. Can be built to operate at any voltage below 250 volts. Typical motor is 4 in. dia. by 2⅜ in. long, weighs 2.6 lbs., and develops 8 oz.-in. starting torque and 0.8 in. synchronous torque. — *Allis-Chalmers Mfg. Co., Milwaukee* 1, *Wis.*

Mention No. 1152 when filling out card.

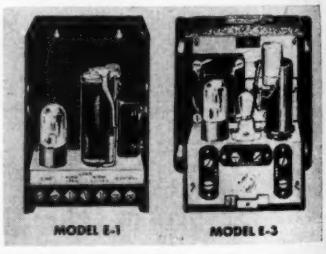
Small Relay

New "Type KX" relay is refinement of "Type K" to provide increased sensitivity and operating range. Has longer coil and can be wound to resistance of 8000 ohms. Coils are single or double wound. Operating voltage is to 175-v. d.c.—*C. P. Clare & Co.*, 4719 *West Sunnyside Ave., Chicago* 30, *Ill.*

Mention No. 1153 when filling out card.

Electronic Relays

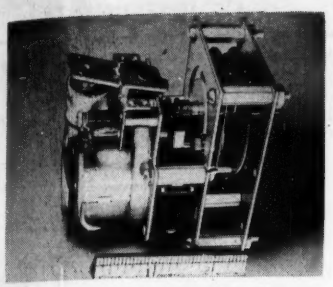
New electronic relays have sealed contacts. "Model E-3" has d-c. control and isolating transformer which permits grounding either side of circuit. "Model E-2" and "E-1" are similar but simplified.—*Emil Greiner Co.*, 20-26 *N. Moore St., New York* 13, *N. Y.*



Mention No. 1154 when filling out card.

Delayed-reset Time-delay Relay

New time-delay relay uses basic "Series 6400" d-c. and "Series 11400" a-c. time delay relay. Makes possible delayed reset proportional to time de-

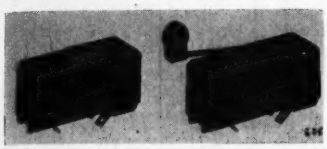


lay, and a circuit reclosure time proportional to length of current interruption. Reset is controlled by escapement mechanism which adds approximately 3/4 in. to length of maker's standard time-delay relay.—*A. W. Haydon Co., 232 N. Elm St., Waterbury, Conn.*

Mention No. 1155 when filling out card.

Magnetic Blow-out Switches

New "MT" series of small-size "Micro" magnetic blow-out switches for switching high-voltage d-c. circuits may be used polarized or non-polarized.

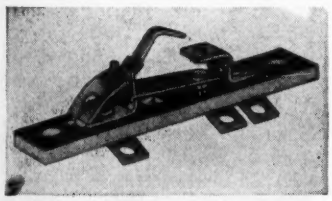


Dimensions are same as standard "Micro" precision switches for a-c. switching. Single-pole double-throw switches now available.—*Micro Switch, Div. of Minneapolis-Honeywell Regulator Co., Freeport, Ill.*

Mention No. 1156 when filling out card.

Snap-action Switches

New "Model 2000" and "Model 2001 snap-action switches employ over-center coil-spring construction which permits wide range of actuating pressures by



specifying spring-element characteristic. UL rating is 6 amps, 125-v. a.c. and 3 amps, 250-v. a.c. Adaptations available in contact size and materials, spring pressures, actuator shapes, mounting holes, and multiple mountings.—*Cherry-Channer Corp., 1488 Skokie Blvd., Highland Park, Ill.*

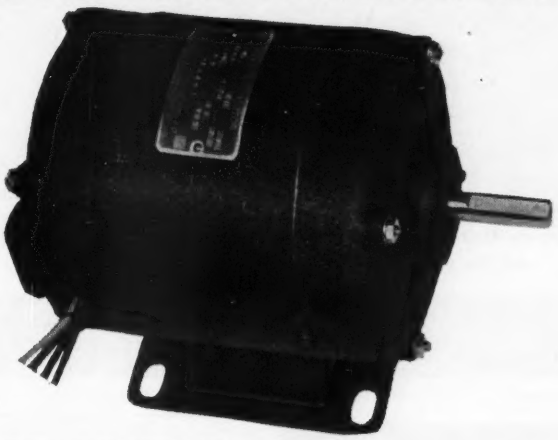
Mention No. 1157 when filling out card.

Switches

New rotary switches are constructed in accordance with applicable JAN and MIL specifications. Features include silver-alloy contacts and slip rings, knee-action rotor, roller-type detent action, and switch stops. Spe-

MORE POWER

GH-368 HYSTERESIS SYNCHRONOUS MOTOR



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FULL 1/16 HP AT 1800 RPM
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- TEMP. RISE 40° CONTINUOUS DUTY
- RATED LOAD 1.2 AMP.
- REVERSIBLE
- PULL-OUT TORQUE 2.5 IN. LB.
  PULL-IN TORQUE 2.55 IN. LB.
  STARTING TORQUE 2.65 IN. LB.

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cial switches are available for high-speed applications with various ratios of on-off time and angular spacing of live contacts.—*The Daven Co.*, 191 *Central Ave., Newark* 4, *N. J.*

Mention No. 1158 when filling out card.

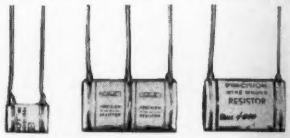
Rotary Selector Switch

New revised line of "Type JA" rotary selector switches are quality switches with large number of contact points and multiple decks. Each deck is self-contained, self-aligning, and easily replaced. "O" ring seal on both shaft and mounting bushing allows watertight mounting.—*United States Instrument Corp.*, 409 *Broad St., Summit, N. J.*

Mention No. 1159 when filling out card.

Precision Resistors

New "Type 61-6 Group" precision wire-wound resistors, supplied on various mounting forms, have stable resistance characteristics and small size.

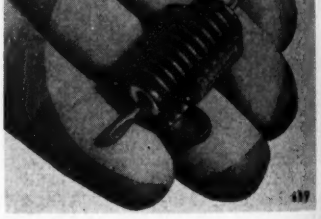


"Type 61-6-17," supplied up to 250 K, has length of 0.406 in. and rating of 0.15 watt per section. "Type 61-6-2," supplied up to 12 megohms, has length of 0.812 in. and rating of 2 watts per section. Six intermediate types available.—*Cole Instrument Co.*, 1320 *S. Grand Ave., Los Angeles* 15, *Calif.*

Mention No. 1160 when filling out card.

Small Power Resistors

New "Dalohm" miniature power resistors are made in 2, 5, 10, 25, and 50-watt sizes. Special silicone material seals resistance element from moisture.

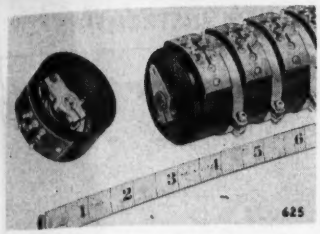


Standard tolerance is 1 percent; tolerances to 0.05 percent can be furnished. Temperature coefficient is less than 0.00002 percent per deg. C.—*Dale Products, Inc., Columbus, Neb.*

Mention No. 1161 when filling out card.

Precision Potentiometer-rheostats

New "C-200 series" precision potentiometer-rheostats are available singly or ganged in both linear and nonlinear windings. Ganging method permits ex-

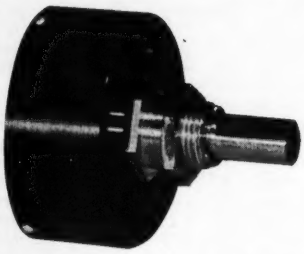


ternal phasing of individual units at any angle. Taps can be furnished at specified points. Resistance range is 10 to 200,000 ohms, up to ±1 percent. Linearity up to ±0.25 percent. Rating is 4 watts. Torque is 1 oz. inch per section. Weight is 5 oz.—*Industrial Div., Dept. I-C, DeJur-Amsco Corp., 45-01 Northern Blvd., Long Island City, N. Y.*

Mention No. 1162 wnhe filling out card.

Precision Wire-wound Potentiometer-rheostats

New "Series 156A Precision Potentiometers" are compact, rugged, and accurate. Specifications include: power



rating—2 watts, linearity tolerance—±1.0 percent, resistance range—5 to 20,000 ohms, resistance tolerance—±5 percent, static starting torque—0.8 oz. in., and weight—1.5 oz.—*Cole Instrument Co., 1320 S. Grand Ave., Los Angeles 15, Calif.*

Mention No. 1163 when filling out card.

Heavy-duty Test Prods

New "Type-H Klipzon" heavy-duty self-holding test prods and leads, designed for clipping to conductors up to #4 B & S gage, are provided with

large sharp self-holding points for piercing insulation. Leads are four-feet long and consist of 16 strands of #30 B & S gage copper with insulation.—*United Technical Laboratories, Morristown, N. J.*

Mention No. 1164 when filling out card.

Sealed Potentiometer-rheostats

New series of waterproof controls are available in wide range of resistances and wattages. Rubber "O" ring shaft creates water-tight seal for pres-

There is a solution to the problem of undesirable vibration—LORD Bonded-Rubber Mountings. The result . . . improved product performance in many ways. LORD Mountings make mechanical equipment smoother . . . quieter . . . easier to operate . . . easier to sell. They protect precision and accuracy . . . increase personnel efficiency and production . . . prolong service life and reduce maintenance costs . . . save vital material . . . cut scrap loss.

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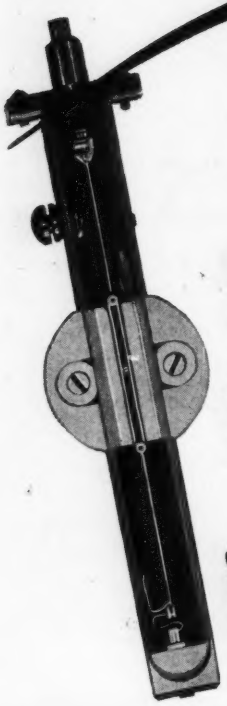

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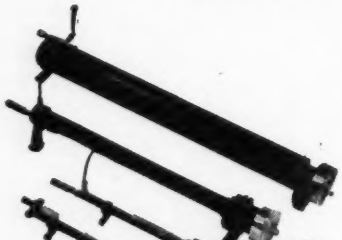

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MODEL 433	20 to 75 Centimeters
MODEL 501	4 to 20 Centimeters
MODEL 402A	2 to 10 Centimeters
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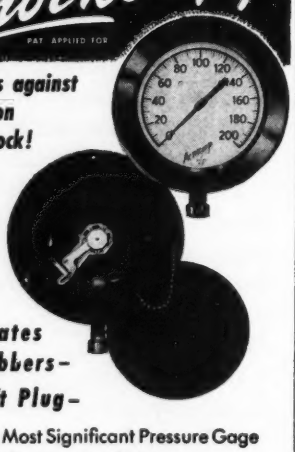

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NEW INSTRUMENTS

sure equivalent to six-foot head of water. Similar "O" ring is used on mounting surface of bushing. Rings meet extreme temperature requirements and are resistant to oils and greases.—*Clarostat Mfg. Co., Inc., Dover, N. H.*

Mention No. 1165 when filling out card.

High-rate-discharge Storage Cells

New group of "Silvercel" storage batteries are 20 amp.-hr. high-rate-discharge cells. "Model 20 HR-15" is for 1- to 10-hr. discharge at rate of 2 to 15 amp. "Model 20 HR-GS" and "20 HR-BS" are for 6-min. discharge at rates up to 150 amp. Dimensions are 4 x 2 x 1.75 in. Weight is 12 oz. Cells are spillproof, leakproof, resistant to shock, and nonpoisonous.—*Yardney Eelctric Corp.*, 105 *Chambers St., New York, N. Y.*

Mention No. 1166 when filling out card.

Solderless Terminal

New "Amp Pre-insulated" flag-type solderless terminal has body insulation. Terminal can be installed with one stroke of tool on standard wires in ranges from #22 to #10. Color-coded plastic sleeve is bonded to thin copper sleeve attached to terminal barrel.—*Aircraft-Marine Products, Inc.*, 2100 *Paxton St., Harrisburg, Penna.*

Mention No. 1167 when filling out card.

Electrical Insulation Material

New "Quinterra Type 3" is asbestos-base silicone-treated high-temperature electrical insulation. It is Class-H insulation, as defined by AIEE standards, for service at 180 C. Used for both inter-layer and wire-wrapping insulation. Dielectric strength is 350 VPM at 180 C., even at high humidity. Supplied in sheets, rolls, and tapes in thicknesses from 3 to 9 mils.—*Johns-Manville*, 22 *E. 40th St., New York* 16, *N. Y.*

Mention No. 1168 when filling out card.

Safety Cleanout Valve

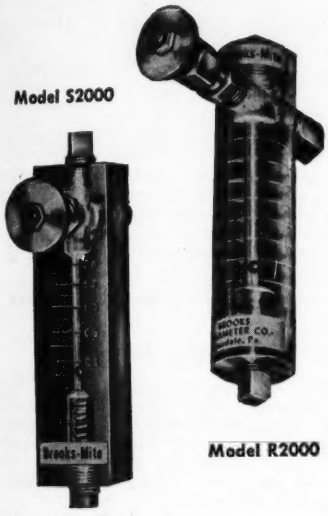
New "Liquidepth" safety cleanout valve is a combination of 3 valves which safely (1) connects buried tanks to

"Petrometer" tank level gage, (2) disconnects level gage from tank and from atmosphere for pumping out water and sludge in tank, and (3) connects suction pump to tank.—*Liquidepth Indicators, Inc., One Star Square, Long Island City, 1, N. Y.*

Mention No. 1169 when filling out card.

Purge Meter

New "Brooks Mite" acrylic-plastic purge meter eliminates packing glands and glass parts. Comes in four sizes with range of 0.01 to 54.0 gal. per hr.

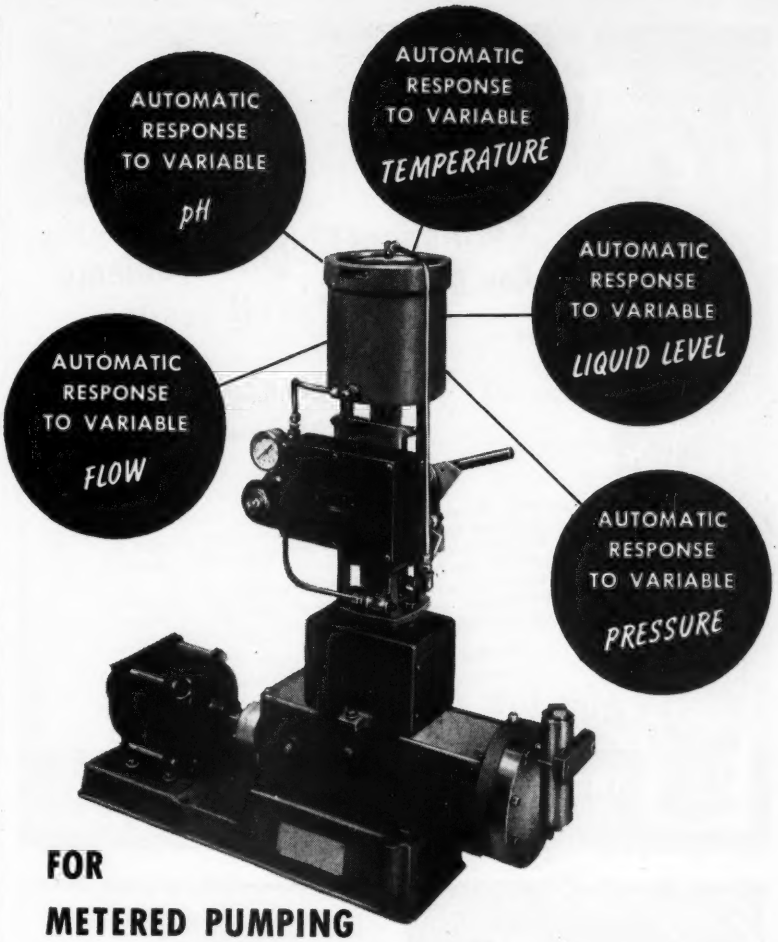


water and 0.2 to 216 cubic ft. per hr. air. Rate of flow is indicated by position of spherical float in metering tube. "Model R 2000" has etched reference marks for approximate flow indication. Direct flow readings are made with "Model S 2000." Both are safe for pressures up to 100 psi. and temperatures to 200 deg.—*Brooks Rotameter Co., Box 432 Z, Lansdale, Penna.*

Mention No. 1170 wnhe filling out card.

Nylon Bearing

New "Nylined" bearing uses "Du Pont FM 10001" bearing material, which performs well with no lubricant; is resistant to abrasion; can stand temperatures above 250 F; and is unaffected by most chemicals. Surface which develops on Nylon has low friction coefficients, damps mechanical vibration, and provides smooth operation.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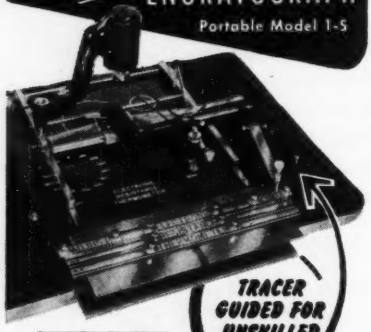

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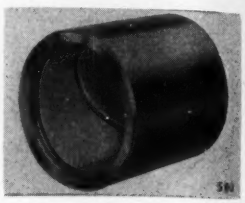
NEW INSTRUMENTS



Inexpensive metal sleeve contains Nylon bearing surface. Can be furnished in plain sleeve or flange type.—*Thomson Industries, Inc., Manhasset, L. I., N. Y.*

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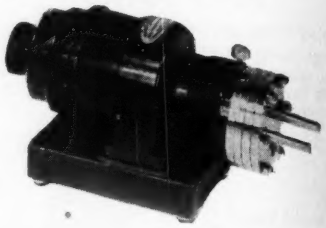
Metering Pumps

New "Maisch" line of small metering pumps are of fixed and variable capacity. Floating stainless-steel gears permit close running tolerances within self-lubricating carbon housing. Pump



heads are demountable and sterilizable. Governor-controlled units provide full power at all speeds from 10 to 750 rpm. Variable-speed transmission units are adjustable from 0 to 50 ml. per sec. Maximum head pressure is 15 psi.—*Mechanical Products Corp.*, 168 *N. Ogden Ave., Chicago 7, Ill.*

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Vibration Isolators

New air-damped unit vibration isolators cover load range from 8 to 16 lbs. Available in "780 series," "780R series." "896 series," and "896R series." The "R" series are ruggedized.—*The Barry Corp.*, 820 *Pleasant St., Watertown 72, Mass.*

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Ceramic Materials

New "Stupalith" ceramic materials can withstand extreme thermal shock because of low coefficient of expansion. Material is produced in two types: with "Zero" thermal expansion and

with near-zero thermal expansion, plus or minus. Materials are lithium aluminosilicate compositions. Can be formed by pressing, extruding, casting and ramming, and can be used to 2400 F. —*Stupakoff Ceramic & Mfg. Co., Latrobe, Penna.*

Mention No. 1174 when filling out card.

Thermoscopic Paints

New series of "Thermindex" temperature-sensitive paints are available in 16 basic shades which undergo color changes at predetermined temperatures. Some exhibit successive color transformation at several temperature levels. —*Tempil Corp., 132 W. 22 St., New York 11, N. Y.*

Mention No. 1175 when filling out card.

Hand Stereoscope

New light-weight hand stereoscope for medical radiology weighs only 4 pounds and occupies only 1 square foot.

Several persons can view one stereo pair at same time. Unit employs Von Helmholtz principle—images are fused through mirrors.—*X-ray Dept., General Electric Co., Milwaukee 14, Wis.*

Mention No. 1176 when filling out card.

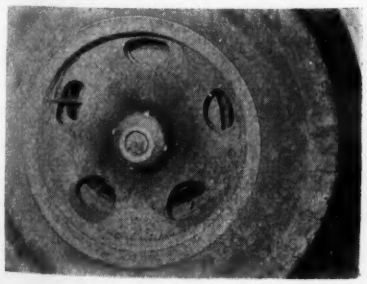
Telescope

New compact, lightweight 60-mm. telescope, only 16.5 in. long, has fast accurate method of focusing through internal movement of prism. Four eyepieces of varying power—15, 20, 30, and 60—are available. Weight is 48 oz. —*Bausch & Lomb Optical Co., 635 St. Paul St., Rochester 2, N. Y.*

Mention No. 1177 when filling out card.

Driveless Counter

New "Mod. 19" driveless counter is hermetically sealed; has no outside driving parts. Regardless of position of wheel or shaft, reading at all times



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faces observer in upright position. Counter (shown mounted on wheel hub) registers backward and forward movement, revolutions, etc.—*Knopf Instrument Co.*, 250 *Culver Ave., Jersey City* 5, *N. J.*

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New portable battery-operated signal flasher uses cold-cathode tube to emit flash of light visible for a mile.

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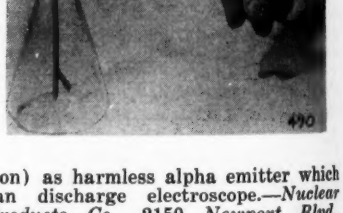
New "Static-master Wand" has polonium foil, (by-product of nuclear fission) as harmless alpha emitter which can discharge electroscope.—*Nuclear Products Co.*, 2150 *Newport Blvd., Costa Mesa, Calif.*



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New "Enamelstrip" is metal coil available in cold-rolled steel, electrogalvanized steel and electrolytic tin plate, brass, zinc and aluminum with adhesive enamel coating in any desired color or shade on one or two sides. Adhesive coating withstands bending and fabricating without cracking or peeling.—*The Coated Coil Corp.*, 501-551 *W. 30th St., New York, N. Y.*

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THE HUMAN FACTOR

Continued from page 1291

gaps, and *G* should have a well-marked crossbar.

3. *Q* needs a strong oblique slash.

4. *W* needs a high center prong to distinguish it from *M*.

5. *M*, *O*, *A*, and *W* should be as broad as they are high.

For numbers, the following recommendations should increase legibility:

1. 2, 3, and 5 need clear gaps.

2. 3 *usually* should have a flat top to distinguish it from 8, except that if read upside down it is less liable to be confused with 5 if it has a round top. Plain lettering (straight limb capitals) is usually more readable than lower case.

When numbers appear through apertures or windows, the opening should show one complete number and at least an identifiable part of another (Fig. 4).

Scale Faces

The selection of scale faces should be governed by the type of reading needed from a particular instrument. These types of reading can be classified as follows:

Fig. 4. Example of poor and good design for "open-window" dials.

1. Check reading—for verifying a null or desired indication.

2. Qualitative reading—for the meaning of deviation from the null or desired indication.

3. Quantitative reading—for the actual numerical value of an indication.

Specific delineation of the best design has not yet been developed, but the following guides are useful:

1. The principle of pointers or indices all in line for normal operation facilitates check reading of groups of indicators.

2. Qualitative interpretations of departures from normal are more accurate for circular dials when the normal is indicated by pointer positioned at "9 o'clock."

3. Linear scales may be preferable for precise quantitative reading.

4. If a scale reflects information being fed into the machine, a circular dial with moving pointer gives the operator a cue to the approximate setting without requiring a close reading.

In general, it is true that the clockwise movement for increase in control design applies to indicators (Fig. 5). Where dials or scales move against a fixed reference point, the absolute movement is secondary in importance to the relative movement.

In aircraft design, much of the instru-

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SM-60	1 100 min.	60 min.	±.002 min.
S-10	1 10 sec.	1000 sec.	±.02 sec.
S-6	1 1000 min.	10 min.	±.0002 min.
S-1	1 100 sec.	60 sec.	±.01 sec.
MST	1 1000 sec.	360 sec.	±.001 sec.
MST-500	1 1000 sec.	30 sec.	±.002 sec.

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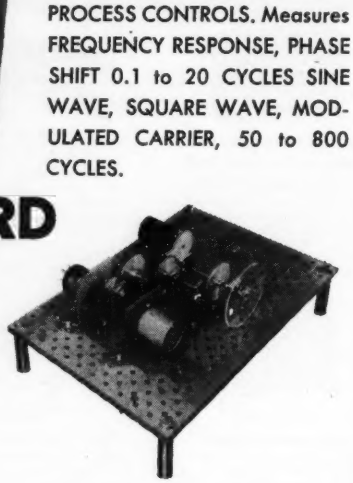

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ment-panel confusion stems directly from making all indicators more quantitative than the functional use required. This tendency is common among design engineers.

Scale Divisions

Scale divisions or markings vary from dial to dial in both frequency of gradu-

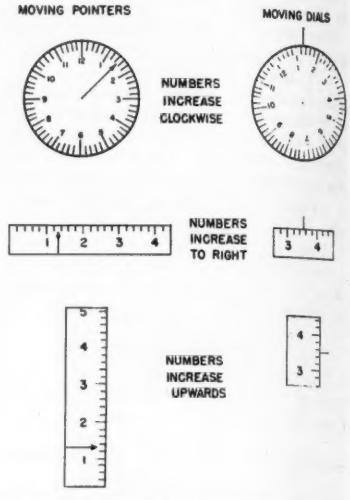

Fig. 5. Recommended designs for scales.

ation and size of interval. If a choice can be made, it should favor a number interval of 1, 2, 3, etc., or the same number multiples of 10 or 100—with ten divisions between consecutive numbers[13] (Fig. 6). Scales divided into intervals of 4 result in reading error. Grether and Williams[14] determined that reading errors increase sharply as the actual space between markings falls below 0.4 inches; a slight increase also

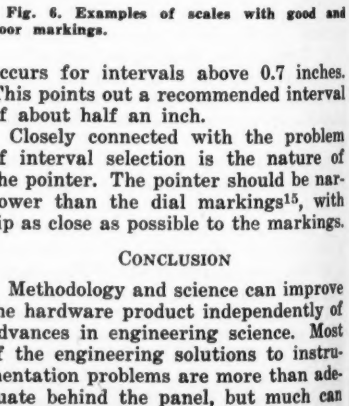

Fig. 6. Examples of scales with good and poor markings.

occurs for intervals above 0.7 inches. This points out a recommended interval of about half an inch.

Closely connected with the problem of interval selection is the nature of the pointer. The pointer should be narrower than the dial markings[15], with tip as close as possible to the markings.

Conclusion

Methodology and science can improve the hardware product independently of advances in engineering science. Most of the engineering solutions to instrumentation problems are more than adequate behind the panel, but much can be done to improve the display on the front of the panel.

It is not desirable to make a bad

instrument or poor panel less bad by minor changes in grouping, marking, lighting, and so forth. Discard orthodox, stereotyped approaches in favor of making all controls and displays mean more to more men—even if it requires a fresh start.

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CONTINUOUS INFRARED ANALYZERS

Continued from page 1299

result in a sizable signal which is sufficient to drive the instrument to accomplish a given analysis. Therefore, without the continued assistance of large organizations the future application of this type equipment to the process industries will be handicapped. Instrument makers have neither the personnel, time, nor financial power to launch extensive application programs to determine just where the continuous analyzers can be utilized.

Discussion

R. L. Martin: I believe we all enjoyed Mr. Devine's paper. One of the things that we all think of in terms of continuous analyzers is how to utilize these instruments for continuous control. If this particular instrument indicates the concentration of a certain component, how does it actually control the distillation column of whatever the process may be. One of the problems that comes up is the automatic standardization on your instrument for critical problems. In other words, is it necessary at times on the critical jobs to come back and standardize your instrument periodically? One question that I would like to ask is what strides are being made to build more stable instruments, so that we can tackle some of the more difficult problems without this problem of standardization at relatively frequent intervals? What can we do to reduce the standardization to a period of once a day or once a week, or even once a month?

J. M. Devine: In the first place, standardization is required to check the zero point drift. Zero point drift in this type of instrument has been caused by two main factors—a change of ambient temperature and a change in the emission of the source of infrared radiation. We have spent a number of years trying to eliminate the effect of these two factors and we have been successful enough to guarantee in a 24-hour period a zero point drift of less than 1 percent of full scale deflection. The instrument is now offered without standardization, without automatic standardization and we have been fairly successful in showing people that automatic standardization is more trouble than it is worth. It is much better if you are going to standardize, to do it manually at every shift change. Automatic standardization complicates the instrument with automatic timers and shifts the bolometer bridge from the measuring circuit to the standardizing circuit. It is a very delicate balance anyway, and it turns out to be much more practical to eliminate automatic standardization. After you do it for a few months you develop faith in the instrument and you gradually cut down the frequency of standardization. If you standarize your controllers must employ a holding system, and you can do that quite easily if you manually standardize, whereas if you automatically standardize you are complicating the system again. Our objective has been to make as simple an instrument as we possibly can.

Martin: I have one more question to bring up which Mr. Devine covered in his talk. How do users apply these instruments? If it is impossible to make a spectrogram of the various components of the mixture in which we are concerned and superimpose a spectrogram and evaluate the problem thereby, the question in the minds of most of the users out here I am sure, is just what can we do to get an indication of the possible use of the instrument? There are very few organizations that feel they can go and spend 5 or 10 thousand dollars for a complete installation just to try something out hoping that it might work without first being relatively sure that it will. I would like to ask Mr. Devine if there is any path that the users may follow to make a relatively intelligent guess as to whether the thing would do the job before purchasing the instrument.

Devine: If you can't afford to buy one, and you can't predict it in spectrograms, the only solution we have is to invite you to send your problem to us and let us try it out on an analyzer in our own plant. If you prepare gas blends representative of the problem, we can predict very nicely the ultimate performance. But, in that respect, I want to caution you on filling gas cylinders. You may not get out what you think you put in.

Mr. Skinner, DuPont: Water vapor being an absorber, will variations in the concentration of that component affect your analysis?

Devine: Water vapor is a fairly strong absorber of infrared radiation, and if it is going to vary in the sample cell we must allow for it. In other words, we must set the instrument up to eliminate the interference of water vapor as we would set it up to eliminate methane and ethane in the problem we cited.

Martin: When the temperature of the sample varies over 30 deg. where the water vapor content would change, is that variation sufficient to warrant filtering of the sample or removal of the water?

Devine: I can't say exactly, but I think with that much change it would be desirable to dry the sample before passing it through the analyzer.

Martin: Where there are inert gases with CO and CO_2 etc. present, what is the procedure?

Devine: The problem is to measure methane in the presence of CO, CO_2, and water vapor all changing in concentration. In that case the methane absorption band, the water vapor absorption band, coincide and overlap. I am quite sure if you eliminated the interference of the water vapor, the CO and CO_2 would be easy and you then would be measuring only the methane change.

Martin: Do you recommend calibrating the instrument with gases and synthetically prepared mixtures?

Devine: We prefer to calibrate against plant streams that are analyzed by some other method. If there is no possibility of doing that, then we will make up or recommend a synthetic gas mixture. We prefer the former however.

Martin: About how long, in your experience should a synthetic fixed cylinder be allowed to stand before use?

Devine: That is a general question. The answer is generally about two weeks, but it depends on the difference in densities of the gases. It takes quite a while to mix them.

Mr. Becker, Diamond Alkali: Can you analyze for water vapor in streams of chlorine? We want to analyze for water vapor.

Devine: As far as infrared is concerned, the answer is yes. I would have to check with corrosion engineers, however on chlorine.

Martin: Would you prefer calcium fluoride optics to rock salt when the dew point goes below 32 deg.?

Devine: I would see no value in using rock salt in the first place. You can get calcium fluoride at the same price. The price, up to this time, has been the dominant factor in using rock salt. Calcium fluoride is now reasonably priced. I would not consider rock salt in a water vapor application.

Mr. Bowers, Standard Oil of Ohio: In the plants now using this type of analyzer, what about type of personnel and special precautions used to keep instruments in operation?

Devine: The practice varies with different organizations. I would say about 50 percent of the applications are maintained by people of laboratory or research classification grade. The other 50 percent are maintained by the instrument department who select a man who is a gadgeteering type of individual with a fondness for new equipment. This individual takes over the analyzer with some special instructions. Baird Associates is giving a course of instructions in maintenance of this equipment for one of the large plants in the Southwest.

Mr. Pearsey, Shell Oil Company: Does the use of calcium fluoride in relation to rock salt optics limit the scope of the instrument? Does it limit the range of transmission?

Devine: With rock salt we can measure the infrared out to about 15 or 16 microns where its transmission starts to fall off. With calcium fluoride we can only go to about 8-½ to 9 microns. However, the absorption bands that are found beyond 9 or 10 microns, the skeletal bands are significant of the vibration of the full molecule rather than the functional group within the molecule. I know of no application where we have had to use rock salt where we wanted to use calcium chloride. We may not have been confronted with that type of application. So far it has not been a hindrance.

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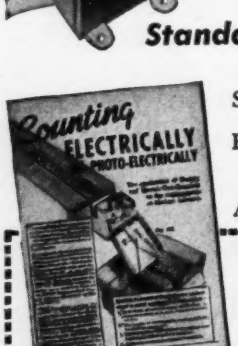

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INSTRUMENTS ON THE MARCH
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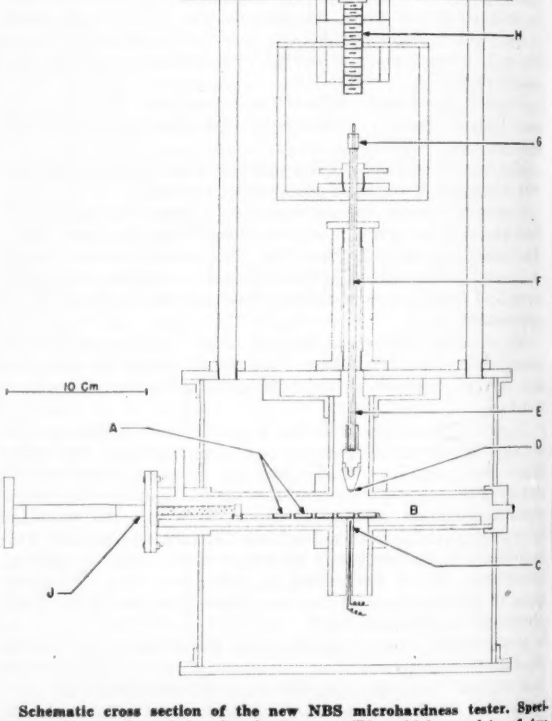
Continued from page 1310

such as the biannual chemical engineering conference and exhibit held by ACHEMA. The next ACHEMACA conference and exhibit will be held in Frankfort/Main from May 18 to 25, 1952. At that time a European meeting of Engineering Chemistry will be arranged.

NBS Micro Hot-hardness Tester

WASHINGTON, D. C.—A microhardness tester for measuring the hardness of electrodeposits at elevated temperatures has been developed by Dr. Abner Brenner of the National Bureau of Standards, according to NBS Technical Report 1569. The new apparatus is based on the diamond-indentation method now used to measure the high-temperature hardness of bulk metals. However, because of the relative thinness of electroplated coatings and their softness at high temperatures, the device has been especially designed to make indentations of microscopic depth under very low loads. Other advantages over previous instruments should also make the tester of value for determining the hot-hardness of bulk metals; in particular, it is expected to find important application in studies of the properties of new types of high-temperature alloys.

Although a number of different devices using indenters of various types have been developed for measuring the



Schematic cross section of the new NBS microhardness tester. Specimens (A) are heated in electric furnace (B), which consists of two tubes jointed in the form of a cross and wound with Nichrome wire. When a specimen comes to rest on anvil (C), indenter (D) is lowered to make pyramidal impression on the specimen. The indenter shaft (E) is a capillary of fused silica. The indenter is attached to a tungsten rod (F), which passes up through the capillary and is held by a collar (G) and set screw. The entire indenter assembly is raised and lowered by a screw mechanism (H) operated by a small motor. The micrometer (J), which moves the carriage containing the specimens past the indenter, serves to locate the indentation so that it can be readily measured with a travelling microscope. Temperature of the furnace is given by the thermocouple within the anvil. In operation, the entire apparatus is filled with an inert gas under slight positive pressure.

hot-hardness of bulk metals, none of these instruments has been found suitable for electrodeposits. The new apparatus overcomes the disadvantages of previous instruments and provides data on electro-deposits at temperatures up to 900 C.

In adapting microhardness testing to high temperatures, it was necessary to use a closed system with an inert atmosphere in order to prevent oxidation of the specimen. Otherwise, the diamond indenter would have to indent a considerable thickness of oxide film before reaching the electrodeposited coating. Also, oxidation occurring after a microindentation had been made would tend to obliterate the impression. Another problem involved the indenter shaft. In order that a light load may be applied accurately, the shaft carrying the indenter must move in a bearing with very little friction. Yet the clearance between the rod and the bearing must be very small to prevent the entrance of air. These problems were met by using in the tester an inert atmosphere slightly above atmospheric pressure and by making the indenter shaft a capillary of fused silica which moves in a dry bearing lubricated with graphite.

Contour Mapping of Optical Surfaces with Light Waves

WASHINGTON, D. C.—Contour maps of precise optical surfaces, whose contour intervals are a small fraction of a wavelength of light, have been prepared by James B. Saunders in the Optical Instruments Laboratory of the National Bureau of Standards, according to Technical Report 1527. By contrast, the usual contour map of a topographic surface may have contour intervals of several feet or more. The optical maps serve the same purpose as topographic maps, except that they reveal ridges and depressions measured in millionths of an inch rather than in feet or inches. For example, optical flats, which are quartz plates for calibrating the precision gages used by science and industry, must be flat within one five-millionth of an inch. Their surfaces must also be parallel to the same tolerance. The new maps can be used for checking the accuracy of these surfaces.

The maps are made by photographing the interference patterns that are formed when light waves are reflected from the surfaces of the specimen and a standard reference of known shape. This is simple interferometry and is common practice in precision measurements of glass optical surfaces. The basic procedure, however, has been modified in the preparation of the new maps.

The customary procedure is to place the surface that is being analyzed close to and almost parallel with the standard surface, leaving a thin layer of air between. The lines or fringes produced by the interference of monochromatic light reflected normally from these two surfaces then give a good indication of the quality of the surface. When proper adjustments have been made, the fringes are one-half wavelength apart. Ordinarily these fringes are relatively broad and appear dark against a bright background. Irregularities in the surface cause these lines to bend, and their appearance is a fairly good measure of how smooth the surface is. However, irregularities of several tenths of a wavelength can go undetected if they fall within the area between two adjacent lines. Even smaller irregularities (up to several hundredths of a wavelength) can be completely hidden within the broad dark bands.

A method has now been worked out at the Bureau by which additional lines are placed between each of the half-wavelength lines. As many as 15 have been added in this way, thus reducing the spacing between lines (the contour interval) to 1/30 wavelength, or 6 ten-millionths of an inch. This results in a much more complete map and brings out those details of the surface that are not shown with the wider interval.

The position of the interference lines can be changed by increasing or decreasing the optical separation of the two surfaces. If this separation is varied in uniform increments

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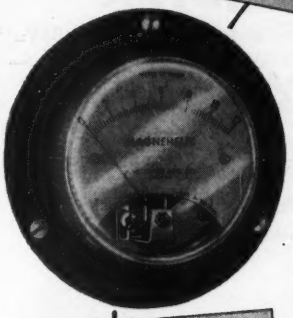

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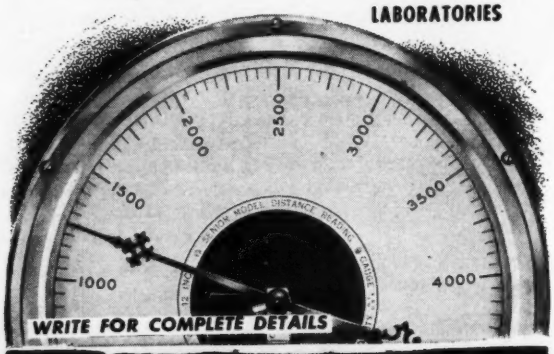

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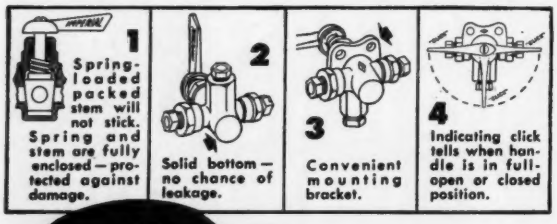

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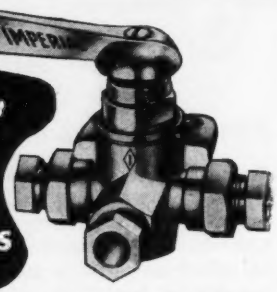

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and successive exposures are made of the fringes in each of the resulting positions, a series of lines representing equal contour intervals is obtained. By choosing the increment properly, the space between two half-wavelength lines can be divided exactly into any desired number of contour

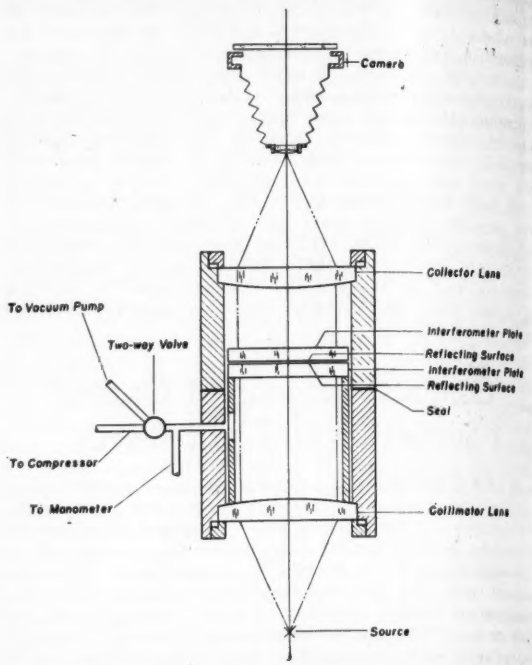


Fig. 1. Apparatus for contour mapping of optical surfaces with light waves.

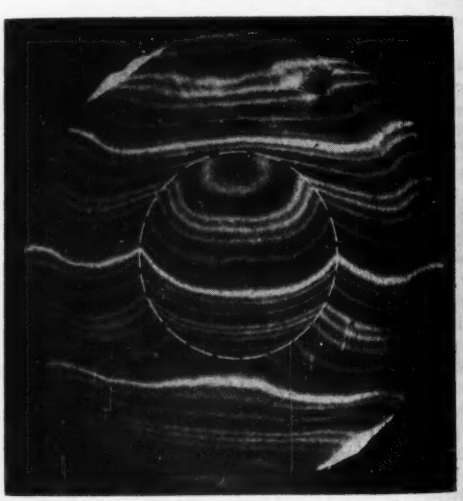


Fig. 2. Three of the conventional optical method interference fringes appear in this illustration (slightly heavier, more intense lines). Seven additional fringes have been introduced between each half-wavelength fringe by reducing in stages the pressure of the air between the surfaces. The result is in effect a contour map having a contour interval of approximately 1/16 wavelength, or 0.000001 inch. It is practicable to reduce the contour interval to a much smaller value.

intervals. The result is a complete contour map of the surface being examined. When a fringe has moved completely through the half-wavelength interval and reaches the position originally occupied by its neighbor, a double exposure is produced. These heavier, double-exposed lines serve as convenient references to indicate the absolute separation of the plates.

The method that has been used at the Bureau for con-

trolling optical separation of the interferometer plates is to vary the density of the air. This is accomplished by enclosing the plates in an air-tight chamber and changing the pressure in equal increments. The exact amount of each increment can be computed from the wavelength of the monochromatic light, the index of refraction of the gas in the chamber, and the total pressure differential of the system.

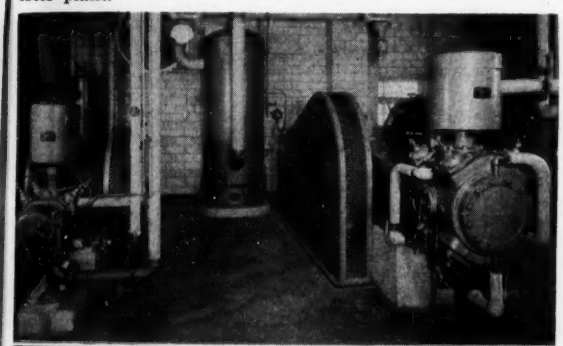
The apparatus (Fig. 1) consists of two cylindrical drums that can be bolted together to form a pressure-tight seal. A collimator lens sealed into one cylinder forms the lower window, and a collector lens in the other cylinder forms the upper window of the chamber. A gas line, connected to a manometer through a 2-way stop cock, permits either compression or evacuation of the gas within the chamber. The camera is focused on the interferometer plate and photographs the successive positions of the lines as they move across the plate.

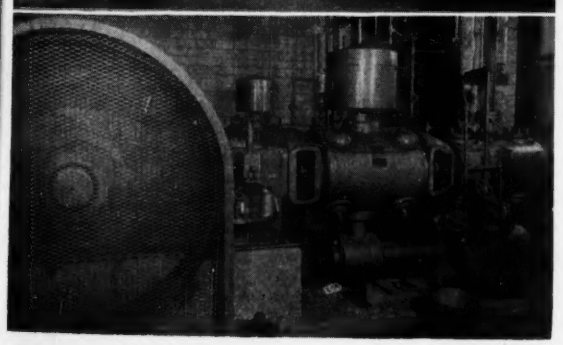
A typical map prepared in this way (Fig. 2) reveals patterns on the surface of a polished specimen arising from the particular stroke and polisher employed in finishing the surface. Although the conventional half-wavelength photographs showed some irregularities, these could not be correlated to give a complete picture of the shape of the surface. Seven additional fringes, however, very clearly pointed out the circular character of the pattern. It was then possible to alter the polishing technique in order to obtain a smooth surface.

COVER FEATURE

The bank of eight Dollinger filters, pictured on this month's cover, removes oil and water vapors from air supplied by the Carbon Ring Compressor for the air-operated instruments on one of the main boilers at the Russell Station of the Rochester Gas & Electric Corp., Rochester, N. Y. Just below the row of eight filters is a standby filter for emergency use when general plant air is sent through the system. Above the filters are reducing valves and gages used in conjunction with the filtering equipment.

Below is pictured the air-supply equipment at the Rochester plant.





For supplying instruments and general plant air at their new Russell Station, the Rochester (N.Y.) Gas & Electric Corporation employs a Pennsylvania Carbon Ring Compressor (top left) mounting a Dollinger "Model DS-350-B-5 Silencer" filter, a Worthington Compressor (top right) and two Ingersoll-Rand Compressors (bottom) mounting "Model DS-450-B-6 Silencer" filters.

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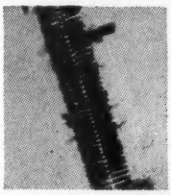

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BOOK REVIEWS

Electromechanical Transducers and Wave Filters

By *Warren P. Mason*

Published by D. Van Nostrand, Inc., New York, 419 pages, (2nd Edition).

Electric-wave filters are important not only in attenuating unwanted frequency bands, but also in coordinating several resonant elements to produce a wide, uniform frequency band. Hence filter theory is used extensively in the design of mechanical systems. Filter theory shows how to combine resonant mechanical and electromechanical elements to produce uniform conversion of mechanical to electrical energy, and vice versa.

Electric network theory is explained, together with the application of the theory to electric and mechanical systems. Acoustic pressure equations and networks are treated theoretically, as is the vibration of membranes and plates. Electromechanical converting systems, including electromagnetic drives, electrostatic drives, piezoelectric drives, and magnetostrictive drives are examined. The factors in the design of electromechanical systems are covered, and the use of electromechanical elements, particularly crystals, in filters is discussed.

The Appendixes include motion of a bar in flexure, viscosity effects in wave propagation, equations for crystals, electrical-network theory, application of network theory, acoustic theory, and electromechanical converting systems.

The titles of chapters are:

1. Introduction
2. Electrical Network Theory
3. Application of Network Theory to Lumped Mechanical Systems
4. Acoustic Equations and Networks
5. Vibration of Membranes and Plates
6. Electromechanical Converting Systems
7. Design of Electromechanical Systems
8. Application of Electromechanical Impedance Elements in Electrial Wave Filters

STYLE AND LEVEL: Mathematics is used throughout, including determinants, partial differentials, and exponential notation for sinoidal functions.

An Introduction to the Theory of Control in Mechanical Engineering

By *R. H. MacMillan*

Published by Cambridge University Press, 51 Madison Ave., New York 10, N. Y.; 195 pages. Price: $6.00.

This book, written for engineers and scientists with knowledge of calculus and some advanced calculus, covers the principles of control, basic types of controllers, and control-system elements, with emphasis on the principles underlying the action of the element or control system. Transmission links and power drives are included. Transient and harmonic responses are analyzed mathematically, using conventional differential equations. Servosystems are analyzed by use of transfer functions. The use of complex numbers, the Laplace transform, and graphical methods for analyzing control-system behaviour are covered. Includes an extensive bibliography, examples, and questions.

Vacuum-tube Voltmeters (2nd Ed.)

By *John F. Rider*

Publisher, John F. Rider, Inc., 480 Canal St., New York 13, N. Y., 432 pages, 215 illustrations. Price: $4.50.

The fundamentals of vacuum-tube voltmeters are presented, including all methods by which d-c. and a-c. voltages are measured. Probes for r-f. and d-c. are described, as are calibration and testing procedures. Commercial equipment is presented in tabular form, with the features of each manufacturer's VTVM listed. The schematic diagrams of the commercial equipments are given, and also frequency-response curves. The concluding chapter is on maintenance and repair. The book is written in nontechnical, nonmathematical language for any man with knowledge of vacuum-tube operation.

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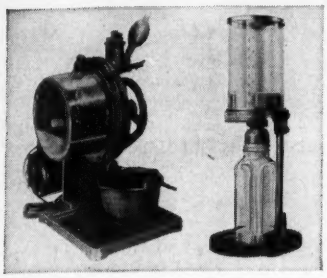

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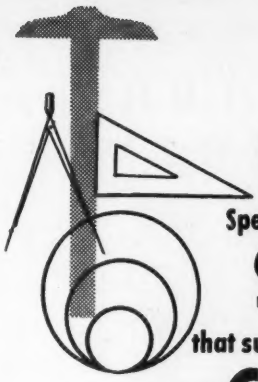

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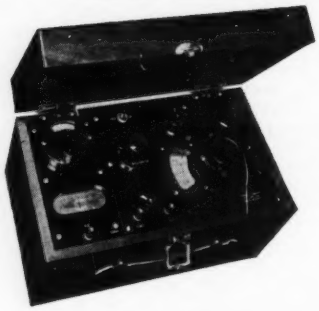

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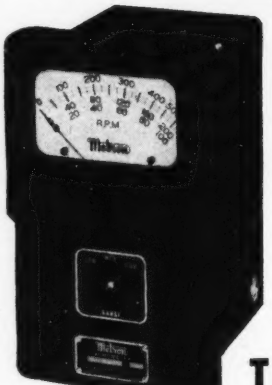

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Report on the Employment Register

Sixth National Instrument Conference & Exhibit

Houston, Texas, September 10-14, 1951

The Employment Register was operated during the open hours of the Exhibit and a total of 106 "Positions Open" notices were posted on the bulletin board. Of this number, 26 had been received prior to the opening of the Conference and Exhibit, the balance of 80 were received during the five day period of the operation of the Register. These Positions Open may be classified as follows:

Positions Open	*At Opening* 9/10/51	*At Closing* 9/15/51
Physicists—Analytical, instrumentation, research, electronic, Government, etc.	4	10
Instrument Engineers—cybernetics, chemical, mechanical, electrical, electronic, design, development, measurement, service, etc.	11	59
Instrument Mechanics—installation, service, maintenance, etc.	4	12
Instrument Technicians—laboratory, assembly, service, etc.	2	9
Instrument Salesmen—sales engineers, sales representatives, sales-service, and manufacture representatives.	3	14
Mathematician	1	1
Specification Writer	1	1
	26	106

The foregoing figures do not represent the exact number of positions open as a number of the notices specified "several" openings and required an indefinite number of personnel.

Interviews

Owing to lack of interview facilities and to the fact that many of the prospective employers' representatives had other duties and could not be in constant attendance at the Register, it was not possible to determine the number of interviwes held between prospective employers and applicants. In practically all cases where employer representatives were attending the Conference and Exhibit, notices were posted along with the Position Open notices that the representatives could be reached at various hotel rooms, exhibit booths, etc. This enabled the applicants to make their own contacts without resorting to the intermediary of the Register.

Employer Representatives

Thirty employer representatives were present for all or a portion of the period and were available for interviews. In addition to interviews these men scanned the files of applicants and took names and addresses of applicants not present at the Conference and Exhibit for later mail contact.

Applicants

The "traffic" of interested individuals through the Register taxed the physical facilities and the time of the personnel attending the Register and it was not possible to keep a count of the individuals who inspected the "Position Open" board. However few men were in actual need of a job and it was obvious from remarks made that the large majority

were present out of curiosity, or seeking comparisons with jobs held, or looking for a position offering advantages over and above the position held, etc.

At the opening of the Register there were 46 applicant cards on file and an additional 51 registered during the week. Since the close of the Conference and Exhibit, 11 men have requested their cards be removed from our files inasmuch as they have obtained satisfactory positions as a result of the Register and 5 prospective employers have advised they obtained qualified personnel as the result of interviews and correspondence. I believe it is logical to assume that other positions were obtained or filled but that the successful applicants or prospective employers have failed to adivse of the fact.

Respectfully submitted,
Lester F. Boss, Pittsburgh Section
In Charge Employment Register

Section Secretaries, Meeting Data and Programs

AKRON
Fred Appel, 932 Columbia Ct., Barberton, Ohio. Tel: SH 3440
Fourth Tuesday, 7:30 P. M., Akron Y.W.C.A.

ALBUQUERQUE
W. E. Bostwick, 2615 Sandia Dr., Bel Air, Albuquerque, N. Mex.
First Monday, Meeting at 8:00 P.M., Science Lecture Hall, Univ. of N. M.

ARUBA
E. H. Pfeffer, P.O. Box 291, c/o Lago Oil & Transport Co., Ltd., Aruba, N.W.I.
First Tuesday, 7:30 P. M., Engr's Club.
Nov. 15-17. Caribbean Instrumentation Conference. Subjects: Tank Gaging, Flow Plan Symbols, Conductivity, Viscosity Measurements, Instrument Training, Water Treatment, Graphic Panels, and Electronics.
Nov. 17. Annual Meeting.

ATLANTA
Virgil Davis, 357 Sixth St., N.W. Atlanta, Ga. Tel. EM. 3042
Third Monday, 7:30 P. M.
Institute of Technology.

BALTIMORE
G. B. Greer, 631 East 36th St., Baltimore 18, Md. Tel: CHesapeake 6879
Second Friday, Meeting at 8:00 P.M., Engr's. Club of Baltimore.

BATON ROUGE
John Q. Bass, 1517 Longwood Dr., Baton Rouge. La. Tel: 3-0283
Meeting monthly, L.S.U. Physics Bldg.

BOSTON
Stephen E. Lord, 60 Braintree Ave., Quincy 69, Mass. Tel: MA 9-1066
Fourth Wednesday, Dinner at 6:30 P. M., Meeting at 7:00 P. M., 99 Club, 99 State St.

CALIFORNIA
D. C. Duncan, Helipot Corp., 916 Meridian Ave., S. Pasadena, Calif. Tel: SY 4-8439
Second Wednesday, Dinner at 6:30 P. M. Meeting at 8:00 P.M., Carolina Dines.

CENTRAL ILLINOIS
H. R. Getz, 723 Laura Ave., Peoria 5, Ill. Tel: 4-2800
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.

CENTRAL INDIANA
Richard F. Rieman, 3550 Euclid St., Indianapolis, Ind. Tel. CH 7462
First Tuesday, Meeting at 7:30 P. M.

CENTRAL NEW YORK
Gilbert Murray, 169 Durston Ave., Syracuse 3, N. Y. Tel: 9-9259
Third Monday, Dinner at 6:00 P. M., Meeting at 8:00 P. M.

CHARLESTON
Fred Gilmer, 418 Beech Ave., Charleston, W. Va.
First Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Kanawha Hotel.

CHICAGO
Floyd E. Ertsman, Rm. 1400 Fisher Bldg., 343 S. Dearborn St., Chicago 4, Ill. Tel: WE 9-0686
First Monday, Dinner at 6:30 P. M., Meeting at 8:00 P. M., Shoreland Hotel.
Dec. 3. Subject: New Instruments and New Developments. Speaker R. W. Jones, Northwestern University. To be held at Illinois Institute of Technology.
Jan. 7. Subject: Precision Measurement by Use of Lightwaves. Speaker: Adam Gabriel, Acme Scientific Co. Sponsored by Committee on Inspection and Gaging.

CHINA LAKE
A. H. Staud, 1004 Michelson Lab., USNOTS, China Lake, Calif. Tel: 77882
Fourth Thursday, Meeting at 8:00 P.M., Michelson Lab, USNOTS.

CINCINNATI
R. J. Eichner, 1900 Courtland Ave., Norwood 12, Ohio. Tel: Jefferson 3130
Second Monday, Dinner at 6:30 P.M., Eng'r. Society Hqs.

CLEVELAND
G. D. Carnegie, 3436 Lorain Ave., Cleveland, Ohio.
Second Wednesday, Dinner at 6:30 P. M., Meeting at 8:00 P.M., Cleveland Eng'r. Society, E. 19th St.

COLUMBUS
E. M. Chandler, 91 E. Como Ave., Columbus 2, Ohio. Tel: JE 9994.
Third Thursday, Meeting at 8:00 P.M., Battelle Auditorium

CUMBERLAND
Clyde Babst, 225 Cecilia St., Cumberland, Md. Tel: 583-W
Fourth Wednesday, Dinner at 6:30 P. M., Meeting at 8:00 P. M., Alighan Shrine Country Club, Baltimore Pike.

DENVER
G. M. Peters, 3191 W. Denver Place, Denver 11, Colo. Tel: GRand 9073

DETROIT
Frank R. Davis, Edison Institute, Dearborn, Mich. Tel: LO 1-1620 Ext. 5517
Third Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Rackham Bldg.
Nov. 20. Magnetic Tape Recording of Sound and Telemetered Data. Audio and Video Products Corp.

EASTERN NEW YORK
Robert W. Carter, Sterling-Winthrop Research Institute, Rensselaer, N. Y.
First Tuesday, 8:00 P.M., Dinner at 6:30 P.M.

GULF COAST
W. N. Sloan, E. I. Du Pont de Nemours & Co., Orange, Texas. Tel: 8411 Ext. 444
Third Tuesday. Meeting at 7:30 P.M., Lamar College, Beaumont, Texas.

HOUSTON
I. K. Farley, Brown Instrument Co., 2123 Travis St., Houston, Texas, Tel: Charter 2511.
Last Monday, 8:00 P. M., University of Houston.

KANSAS CITY
H. H. Schmall, 3706 Benton Blvd., Kansas City 3, Mo. Tel: AR 4808
First Tuesday, 7:30 P.M., U. of Kansas City.
Dec. 4. Subject: Inverse Derivative. Speaker: C. B. Moore, Moore Products Inc. Philadelphia, Pa.
January 8, Subject. Refinery Process Instrumentation. Speaker, David M. Boyd, Jr., Universal Oil Products Co., Chicago, Ill.

LOUISVILLE
C. M. Bosworth, 203 Arbor Park, N., Lo., Ky.
Fourth Tuesday, Meeting at 8:00 P.M., Seagram Auditorium.

MONTREAL
L. E. Henne, Bristol Co. of Canada Ltd., Dominion Square Bldg., Montreal, Quebec, Can. Tel: UNiversity 6-4725.
Last Monday, 8:00 P. M., Mechanics' Institute.

NEW JERSEY
L. H. Ballinger, 2371 Channing Ave., Westfield, N. J. Tel: Westfield 2-0765M
First Tuesday. Meeting at 8:00 P.M., Essex House, Newark.

NEW ORLEANS
W. H. Haney, 2927 Music St., N. O. 22, La.
No Regular Date, Meeting at 8:00 P.M.

NEW YORK
F. B. Leslie, 8856 Commonwealth Blvd., Bellerose 6, N. Y. Tel: FI 7-0645
Last Monday, Dinner at 6:00 P.M., Meeting at 7:45 P. M., Hob Nob Club, 108 E. 41st St.
Dec. 17—Student Night. Subject: The Development of pH Instrumentation. Speaker: George Butler, Beckman Instrument Co. "Information at Work"—a motion picture presentation of The Taylor Instrument Companies.
Jan. 28. Subject: Instrumentation Problems on the Aramco Oil Pipe Line. Speaker: Fred Rich. A color film will be shown of the construction of this line in Saudi Arabia.

NIAGARA FRONTIER
Mrs. James L. Martin, 34 Manning Rd., Eggertsville 21, N. Y. Tel: Windsor 0087
Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., N. Y. State Inst. of Arts and Sciences, Buffalo.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9.

NORTHERN CALIFORNIA
Bert L. Anderson, 1951 47th Ave., San Francisco, Calif. Tel: SEabright 1-5030
Third Monday, Dinner 6:30 P. M., Meeting 8:00 P. M., Spengers Grotto.
November Meeting. Field Trip to C & H Sugar Refinery at Crockett includes dinner by C & H.

NORTHERN INDIANA
J. Baum Beckman, 7145 Wicker Ave., Hammond, Ind. Second Tuesday, Meeting at 7:30 P.M., Whiting Community Center, Whiting, Ind.

OAK RIDGE
J. Lundholm, Jr., Eff. A-3, Apt. 214, Oak Ridge, Tenn. Tel: 5-6539
First Wednesday, Meeting at 7:30 P.M., Knight's of Columbus Hall.

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada. Tel: HU-7114
Third Thursday, Meeting at 8:00 P.M. Friendship Hall, College St. United Church, Toronto

PANHANDLE
W. F. Hoag, Phillips Chem. Co., Box 277, Dumas, Texas. Tel: 241.
Third Tuesday, Meeting at 8:00 P.M.

PHILADELPHIA
R. A. Trenner, Energy Control Co. Rm. 306, 3147 N. Broad St., Philadelphia 32, Pa. Tel: SA 2-7900
Third Wednesday, Meeting at 8:00 P.M., Bellvue Stratford Hotel.

PITTSBURGH
W. C. Langerman, Fisher Scientific Co., 711 Forbes St., Pittsburgh 19, Pa. Tel. Express 1-1330.
Fourth Monday, meeting jointly with the Technical Committee on Inspection and Gaging. Dinner at 6:30 P.M., Meetings at 8:00 P.M., Roosevelt Hotel.
Nov. 26, Industrial Instruments Division. Subject: Instrumentation Used in Radioactive Tracer Work in the Glass Industry. Speaker: K. M. Laing; Development Dept. Pittsburgh Plate Glass Co. Creighton, Pa. Technical Committee on Inspection and Gaging. Subject: Inspection of Refractories. Speaker: Charles. R. Ayers, Superintendent of Plant, Harbison Walker Company, Windham, Ohio.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa. Tel: 2-3349
Fourth Tuesday, Meeting at 8:00 P.M., G. E. Community Center, East Lake Rd., Erie, Pa.
Nov. 27. Subject: Measurement & Control of Flow & Liquid Level. Speaker from Taylor Instrument Co.
Jan. 22. Subject: Measurement & Control of Pressure. Speaker from The Bristol Co.

RICHLAND
T. H. Quinn, 1513 Goethals Dr., Richland, Wash. Tel: 7-8717
Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., 1201 Granite Bldg., Rochester 4, N. Y. Tel: Monroe 4610R
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.

SARNIA
L. J. Hall, 730 Talfourd St., Sarnia, Ont., Canada. Tel: EDgewater 2258.
Second Friday, 8:00 P. M., Moose Hall.

SOUTH MICHIGAN
Lyle J. Draper, 2233 Oakland Dr., Kalamazoo, Mich.
Fourth Wednesday, 8:00 P. M., Dinner at 6:30 P. M., Chicken Charlie's, Kalamazoo.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas. Tel: 122-W
First Wednesday. Meeting at 7:30 P.M.

ST. LOUIS
W. G. Lee, 4710 Delor St., St. Louis 16, Mo. Tel: FL 8516.
First Wednesday, Meeting at 8:00 P.M., Engineer's Club of St. Louis.
Dec. 5. Subject: Inverse Derivative. Speaker: C. B. Moore, Moore Products Inc., Philadelphia, Pa.
Jan. 9. Subject: Refinery Process Instrumentation. Speaker: David M. Boyd, Jr. Universal Oil Products Co., Chicago, Ill.

TOLEDO
P. H. Girkins, 418 Waggoner Blvd., Toledo 12, Ohio. Tel: LA 6505
Third Tuesday, Meeting at 8:00 P. M., Service Bldg., Toledo Edison Co.

TENNESSEE
James L. Williams, 2237 Bruce St. Kingsport, Tenn. Tel: 2079-L
Fourth Thursday, Civic Auditorium.

TULSA
S. M. Bagwell, 1544 E. 35th Pl., Tulsa 5, Okla. Tel: 7-6822
First Monday, Meeting at 7:30 P.M., Engineering Bldg., Tulsa Univ.
Dec. 3. Subject: Inverse Derivative. Speaker: C. B. Moore, Moore Products Inc., Philadelphia, Pa.
Jan. 7. Subject: Refinery Process Instrumentation. Speaker: David M. Boyd, Jr., Universal Oil Products Co., Chicago, Ill.

TWIN CITIES
Jerome J. Schwab, Engineering Sales, 516 Guardian Bldg., St. Paul 1, Minn. Tel: GArfield 0601
Fourth Tuesday, Dinner at 6:30 P.M. Coffman Memorial Union, U. of Minn.

WASHINGTON
Raymond E. Miller, 1-205 Naval Ord. Lab., White Oak, Md. Tel: JU 7-6742
Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.

WAYNE COUNTY
J. R. McCauley, 18073 Archdale, Detroit 19, Mich. Tel: KE 1-5239.
Third Monday, Meeting at 8:00 P.M., Larson's Cafe, Lincoln Park, Mich.

WILMINGTON
J. E. Charsha, Jr., Hammel-Dahl Co., 1000 Washington St., Wilmington 11, Del. Tel: 2-6694
Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.

ISA EMPLOYMENT SERVICE

Forward your letter to INSTRUMENT SOCIETY OF AMERICA 921 Ridge Ave., Pittsburgh 12, Pa.

INSTRUMENT ENGINEER. Capable instrument man for the Houston, Texas branch of company of design engineers and constructors for the petroleum and chemical industries. Excellent opportunity for qualified man to get in on the "ground floor". Beginning salary $450 per month with 6 month merit review. Box 592.

INSTRUMENT ENGINEER. Responsible for operation, installation, and maintenance of static and dynamic measuring and recording equipment including oscilloscopes, electro-mechanical oscillographs, strain gages, variable reluctance bridges using strain gages, inductance and capacitance type pickups for purpose of measuring high and low frequency vibrations and transient signals of displacement, velocity, acceleration, pressure, strain, temperature, etc. Considerable ingenuity required to develop experimental setups for aeronautical, structural, ordnance, and industrial programs. Position offers unlimited opportunities depending on initiative and ability of individual. Salary commensurate with training and experience. Location Texas. Box 593.

INSTRUMENT ENGINEERS. Mechanical and Electrical Engineers for field service, design and estimating in the field of pneumatically and electrically operated controls. Headquarters Pittsburgh, Pa. Box 594.

FIELD INSTRUMENT ENGINEER. Trouble diagnosis and maintenance of instruments in field of pyrometry and instrumentation. Should have good electrical background and some experience or knowledge of instruments. Position permanent with good future, full travel allowance, all company benefits. Location Chicago Area. Box 595.

INSTRUMENT DEVELOPMENT ENGINEER. Large eastern chemical industrial concern has opening for an outstanding instrument engineer with B.S. or M.S. degree in chemical, mechanical or electrical engineering. Candidate should have a solid background in physics. Prefer few years industrial experience. Work involves sufficient knowledge of instruments and their operation to select and apply these instruments to the measurement and control of various chemical processes. Candidate should have sufficient knowledge to modify available instruments to meet special applications. Salary and opportunity above average. Reply should include age, education, experience, salary requirement and address. Location Delaware. Box 596.

INSTRUMENT DEVELOPMENT ENGINEER. Requires man with thorough knowledge of pressure actuated mechanical instruments and allied devices. At least two years design experience on pneumatic controllers. Education of, or equivalent to, graduate mechanical engineer. Location Southern New England. Box 597.

ELECTRICAL, ELECTRONIC ENGINEER OR PHYSICISTS. For flight research department instrumentation work, involving design and test of data measuring circuits and servo systems. Give education and experience in first letter. Replies held in strict confidence. Location Western N. Y. State. Box 598.

ELECTRICAL ENGINEER. With experience and ability to devise controls for water conditioning processes. Permanent position. Location N. Y. City. Box 599.

SENIOR ENGINEERS. Experienced on any of the following: recorders, potentiometers, pressure and temperature sensing instruments. Salary commensurate with experience and ability. Location California. Box 600.

INSTRUMENT ENGINEER. Experienced in product development to work on boiler plant controls, by a long established manufacturer of level, temperature and pressure controlling devises. Must be capable of initiating designs, developing equipment and handling the application of new products. Salary will depend on qualifications. Group insurance and pension plan. Location Western Pennsylvania. Box 601.

INSTRUMENT SALESMAN. By Philadelphia organization to cover local territory. We have a complete line of industrial control equipment needed by an ever increasing industrial market. Base salary, commission and expenses. Give full information in first letter concerning education, experience, etc. All replies confidential. Box 601-A.

INSTRUMENT INSTRUCTOR. To train instrument men in the operation and maintenance of new instruments and related equipment being added throughout plant as well as training on the operation and maintenance of conventional instruments now in the plant. To keep instrument men informed of the many changes and modifications being added to the instruments already in use and arrange demonstrations and instructional periods where necessary. Requires a man of good mechanical ability, experienced in the maintenance of instruments and able to talk the "language of the shop men". Much planning and ingenuity will be required in determining best instruction methods, assembling demonstration units, etc. Location Michigan. Box 602.

INSTRUMENT TECHNICIANS. Experienced on installation, repair, testing and calibrating major makes of instruments and controls. Location Georgia. Box 603.

INSTRUMENT TECHNICIAN. Test, locate faults, adjust, maintain, repair and install any type of recording, regulating, measuring, and control instrument such as pressure, vacuum, temperature, flow and level control, and electrical meters. Calibrate instruments to coincide with an established standard. May operate Orsatz gas analyzer. May devise or develop instrument for a specific need or duty. Work with minimum supervision from prints, sketches, written and oral instructions. Rate start $1.90 per hr., after 3 mos. $2.00, after 6 mos. $2.15. Paid vacations, group hospital and surgical insurance for employee and dependents, paid holidays, sick and accident benefits, group life insurance. Location, an operating chlorine plant with organic by-products in Tennessee. Box 604.

INSTRUMENT MECHANIC. Opening in large oil refinery in St. Louis area. Must be experienced in pneumatic and electric controls as used in an oil refinery or chemical plant. Normal work week 40 hrs. Hourly rate $2.22. Liberal benefit plans and good working conditions. Box 605.

CAMERA SERVICEMAN. Unusual opportunity for competent technician with practical experience covering aerial cameras in maintenance, overhaul and repair. Mechanical knowledge of gun cameras, motion picture cameras, data recording cameras and high speed cameras helpful. Give training, experience and salary desired in first letter. Location Southern California. Box 606.

ELECTRICAL INSTRUMENT MECHANIC. Vacancy in Meter and Instrument Division of large manufacturing company for 1st class electrical instrument repair man for switchboard instruments (voltmeter, ammeter, wattmeter, etc.), portable instruments, laboratory type instruments, watthour meters, relays, general testing. Location Philadelphia, Pa. Box 607.

SALES MANAGER. Mnust have had experience in sales management and a strong background of both engineering and sales in the non-electrical instrument field. Thorough understanding of orifice metering principles desired. Age preference 35-40. Excellent long range opportunity. Apply by letter giving full experience, education and salary expected. Location Northern Ohio. Box 608.

RESEARCH ELECTRONICS ENGINEER. An electronic engineer with 7 yrs. experience in the field of electronic circuit design. Experience as head of electronics group in development of aircraft electronic instrumentation desired. Duties would primarily involve design of circuits for instrumentation with few supervisory duties. Will be required to be familiar with standard methods and references in his field. A hard germ of practicality is required. Location Buffalo, N. Y. Box 609.

ASSOCIATE RESEARCH ELECTRONICS ENGINEER. Investigation and development of varied and occasionally complex phases of projects in electronics or electro-mechanics. Must be capable of design, construction, test and operation of breadboard and pilot model devices, as well as related work as assigned. Should be proficient in the use of instruments of precision and be familiar with standard methods and references in his field. Must be able to prepare and edit full reports, coordinating the reports of other engineers working on the same project. Location Buffalo, N. Y. Box 610.

GOVERNMENT SERVICES

To apply for any of the following Federal Agency positions, write direct to the Agency holding the position, for official application form.

ELECTRONIC SCIENTIST. Plan and study problems involving instrumentation and integration of man-machine combinations into complete shipboard systems; experimental study and evaluation of these systems and their parameters. Supervision of personnel. $5400 per annum. U. S. Navy Electronics Laboratory. San Diego, California.

MECHANICAL ENGINEERS (2). Technical reports on test facilities, test runs, mechanical design, test run measurements calibrations, and special technical investigations on experimental procedures. Supervise installation, operation, alterations, assembly, disassembly, and calibrations appurtenant to facilities and test installations. $5400 per annum. U. S. Naval Ordnance Test Station. Pasadena, California.

AERONAUTICAL ENGINEER. Head of Air Frames Test Branch; supervise formulation of test plans and instrumentation requirements. Determine desirability of developing experimental test vehicles and 1 or specialized instrumentation. Provide consulting services for other divisions and contractors on testing, design and instrumentation of scale model guided missiles and their components. $6400 per annum. U. S. Naval Air Missile Test Center, Point Mugu, California.

THE MICROWAVE SPECTOGRAPH
It's Use as an Analytical Instrument

By R. H. HUGHES*

ABSTRACT. This paper presents an extensive and thorough discussion of microwave spectroscopy, including: a history of its development and use, theory of operation, a description of working models, as well as the use of this type of spectrograph in qualitative and quantitive analysis. Equations are given for absorption coefficients in single and multi-component mixtures, with discussions of their significance in application. Pending further development in this field, the microwave spectrograph is shown to have much promise in the solution of many analytical problems.

Microwave spectroscopy is a comparatively new branch of spectroscopy utilizing radiation with wave length of the order of one centimeter. This region is similar to the infrared in that the absorption of radiation by material is detected more readily than the emission. The reduction in intensity of radiation of a known frequency on passage through the sample is measured.

In a gas at low pressures, absorptions take place at very sharply defined frequencies—the rotational frequencies of the molecules. These rotational frequencies can be calculated when the structural parameters of the individual molecules are known. Solids and liquids give absorptions which depend upon the interactions of the molecules as well as upon their structural parameters; therefore, these absorptions cannot be so readily calculated.

Because each absorption by a condensed phase is broad and covers a large portion of the spectrum, the spectra probably will not be very useful for chemical analysis. No discussion of the absorptions by liquids and solids is included in this paper.

History of Development and Use

Microwave spectroscopy seems to have started with the work of Cleeton and Williams at the University of Michigan on the inversion spectrum of ammonia in 1934[1]. Because of their use of gas at atmospheric pressure in the absorption cell, the resolution they obtained was very poor. They did not detect the fine structure of this spectrum. This was the only paper on microwave spectroscopy before World War II.

During the war the microwave absorptions by water and oxygen were studied because of their importance to radar transmission. Since the war there has been considerable activity in this new field as evidenced by the publication of well over 100 papers. This work has been chiefly undertaken by physicists and physical chemists familiar with electronic techniques.

The present instrumentation in this field owes its existence largely to the wartime developments in microwave radar. Many of the components and techniques developed at the Radiation Laboratory at the Massachusetts Institute of Technology, the Bell Telephone Laboratories, the Westinghouse Research Laboratories, and other large laboratories in radar research have been used in microwave spectroscopy.

The reflex klystron, which is the energy source most commonly employed, was a wartime development. Post war development of the klystron by the Raytheon Manufacturing Company has given several new tubes which greatly increase the wave length coverage available to the spectroscopist. The precise frequency measuring techniques are modifications of those developed during the war. The application of modulating techniques to spectrographs in the last few years has increased their sensitivity very markedly.

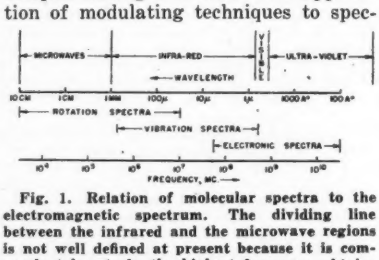

Fig. 1. Relation of molecular spectra to the electromagnetic spectrum. The dividing line between the infrared and the microwave regions is not well defined at present because it is commonly taken to be the highest frequency obtainable from a continuous wave oscillator. Microwave spectral studies have been done from 3 cm. to 2 mm., but more commonly between 1.5 cm. and 5 mm.

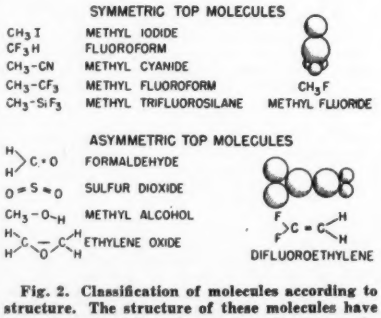

Fig. 2. Classification of molecules according to structure. The structure of these molecules have been determined by microwave spectroscopy. In the CH_3, CF_3, and SiF_3 groups the unique atom is surrounded symmetrically by the three identical atoms. This three-fold symmetry gives the molecule two equal principal moments of inertia. Because the asymmetric tops have no symmetry, or at most a two-fold symmetry, their three principal moments of inertia are all different. In ethylene oxide, one hydrogen atom at each end is above the plane of the C-O-C group and the other is below.

Because the

Microwave Spectra

A plot of the frequencies at which a substance absorbs radiation constitutes the absorption spectrum of the substance. As molecules are the chief absorbers in the microwave region and

The microwave spectroscope has been utilized extensively by physicists and chemists to study problems in atomic and molecular structure. Atomic spectra studies have given information on the electronic levels of cesium and of hydrogen. From the moments of inertia obtained from molecular rotational spectra, bond lengths and angles as well as unknown nuclear masses can be ascertained. From the nuclear quadrupole effects which appear as fine structure in many molecular spectra, the spin of nuclei and information concerning the electronic structures of molecules are available. For a comprehensive discussion of these phenomena see the excellent review articles of Gordy[2] and Coles[3].

An important instrumental application of microwave spectroscopy is accomplished in the atomic clock*. The ammonia molecule takes the place of the balance wheel and hair spring in the usual clock. The inversion frequency of this molecule as measured by a microwave spectrograph incorporated in the instrument governs the rate of the clock.

The analytical applications of microwave spectroscopy have not been exploited to any considerable extent. A good paper on analysis with microwave spectroscopy has been written by Dailey[4]. His paper deals more with the theoretical aspects of spectra but gives less experimental detail than does this paper.

* Westinghouse Electric Corp., East Pittsburgh, Pa.

NOTE: Presented before the Fifth Annual Convention of the Instrument Society of America, at Buffalo, N. Y., Sept. 18-22, 1950.

* *Instruments*, February 1949.

THE AUTHOR

Richard H. Hughes received a B.A. in chemistry from Colorado College in 1940. He earned an M.A. in chemistry in 1942 from the University of Texas, and a Ph.D. in chemical physics from Harvard in 1948. While at Harvard he built the first successful Stark-effect microwave spectrograph with an alternating potential applied to the electrode. For the past two years he has worked at Westinghouse Research Laboratories in the field of microwave spectroscopy.

are the main substances studied in microwave spectroscopy, molecular spectra will now be described. The relationship between molecular spectra and the electromagnetic spectrum is shown diagrammatically in Fig. 1.

The absorption spectrum of a molecule can be divided into three main divisions depending upon which changes in the molecule give rise to the absorption. In the visible and ultra-violet regions, the absorptions are caused by the change of the electronic levels of the bonding electrons; in the near and far infrared, absorption arises from the excitation of vibrations in which the atoms move with relation to each other; in the far infrared and microwave spectrum, absorptions appear when a molecule changes its rotational motion. Because microwave spectrographs do not go below one millimeter at present, rotational spectra are the usual occurrence in microwave spectroscopy.

The rotational spectrum of a molecule cannot be calculated by ordinary classical mechanics. If a molecule were entirely analogous to a rotating top, it could rotate with any velocity and would absorb energy over the entire spectrum. Because a molecule is so small, it must obey the laws of quantum mechanics. There will be only discrete velocities at which the molecule can rotate and thus only discrete frequencies at which it can absorb radiation. Formulas have been derived by quantum mechanical methods which enable one to calculate the absorption frequencies for molecular rotations when the principal moments of inertia of the molecule are known[5].

The results of some of the calculations can be seen in the spectra in Fig. 3. The molecule must be capable of interacting with the radiation if a spectrum is to be observed; a molecule must have either a permanent electric dipole moment or a permanent magnetic dipole moment of sufficient magnitude if the radiation is to act on it. As very few molecules have magnetic moments of appreciable magnitude, electric dipole moments are usually necessary to give a rotational spectrum. Molecules with unpaired electrons such as oxygen and nitric oxide do have large enough magnetic moments to interact with the radiation, however.

Types of Molecules and Their Rotational Spectra

Molecules may be divided into three main groups, namely: linear, symmetric top, and asymmetric top molecules, depending upon their structure (see Fig. 2).

Linear and Symmetric Top Molecules

As linear and symmetric top molecules give essentially the same kind of spectra, they can be discussed together. Linear and symmetric top molecules are the same in that they have two equal principal moments of inertia and a third unique principal moment. Linear molecules (all atoms in a straight line) are different in that the unique principal moment is zero; i.e., the moment about the axis of the molecule is zero.

The simple absorption spectra illustrated in Fig. 3 for linear and symmetric top molecules are typical. The spectrum of OCSe was calculated using constants determined from microwave data by Strandberg, Wentink, and Hill[6], and the spectrum of CF_3H was calculated from the data of Gilliam, Edwards, and Gordy[7]. As there is a definite pattern to the lines, a line can be identified by its position in the spectrum.

Diatomic molecules, the simplest linear molecules, studied in microwave spectroscopy include iodine monochloride, bromine fluoride, carbon monoxide, and oxygen gas. Triatomic and larger linear molecules which have been examined are carbonyl sulfide, nitrous oxide, hydrogen cyanide, chloracetylene, cyano-acetylene, and several others. As the absorption frequencies of a molecule are inversely proportional to the moments of inertia, the larger and heavier molecules give absorptions at lower frequencies.

Asymmetric Tops

Asymmetric tops (molecules with three different principal moments of inertia) are exemplified by sulfur dioxide, formaldehyde, or ethylene oxide, and show very complicated spectra. On examining Fig. 3, the reader will note that there is not much order to the spectrum of SO_2. The SO_2 spectrum was taken directly from the work of Dailey and Wilson[8]. As the intensities of all the lines were not published, some of the intensities indicated may be in error.

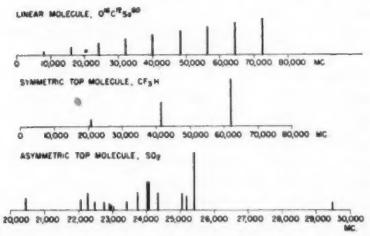

Fig. 3. Three types of molecular rotation spectra. Linear and symmetric top molecules, with their two equal principal moments of inertia, give very simple spectra, consisting of equally spaced lines widely separated. The structure of one of these molecules must be known only roughly for the identification of a transition to be made. The three different principal moments of inertia of the asymmetric tops give rise to the very large number of apparently unordered lines in their spectra. The spectral region shown for SO_2 is much smaller than that shown for the other molecules.

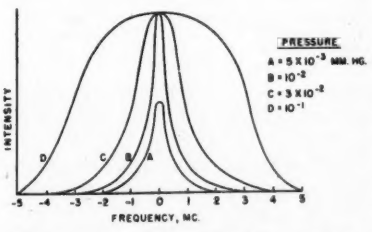

Fig. 4. Absorption vs. frequency as a function of pressure for a microwave absorption line. At low pressures the peak absorption increases with increasing pressure while the line keeps the same width at the half-power points. At high pressures, 10^{-2} mm. of Hg. and higher, the peak absorption remains constant and the line width increases with increasing pressure.

Calculations of the absorption frequencies of asymmetric tops are difficult because there are no simple, closed formulas for these frequencies as there are for those of symmetric tops. The spectrum depends on the asymmetry of the molecule, changing radically as the shape of the molecule is changed. Although it may be possible to arrange the lines into bands for any particular molecule, there are usually so many overlapping bands that this ordering is very difficult to accomplish, except possibly for certain slight asymmetric tops.

Asymmetric top spectra are usually very hard to identify even if the structure of the molecule is roughly known, because the positions of the lines are hard to predict accurately enough to identify them. It is necessary to identify at least some of the lines by their Stark-effect patterns.

There are two spectra in the microwave region which involve molecular rotation in a different manner. In the ammonia spectrum, which is caused by the turning inside out of the molecule, the fine structure results from the effect of the rotation on this inversion. In methyl alcohol, a complicated spectrum rises because of the interaction of molecular rotation with the internal rotation of the hydroxyl group around the methyl group.

There are other effects in microwave spectroscopy, such as the quadrupole effect and the effect of excited vibrational states, which are too specialized to be discussed here and would contribute little to this discussion.

Line Widths and Absorption Coefficients

Line widths are a very important factor in the apparent resolution of the spectrograph. In contrast with other fields of spectroscopy, the line width in microwave spectroscopy limits the resolution; the inherent resolving power of the spectrograph is much greater than that needed to resolve the lines. The line shape, intensity being the ordinate and frequency the abscissa, is shown as a function of pressure in Fig. 4.

It is to be noted that in the low pressure region, the line width is independent of pressure and is between 0.2 and 0.5 mc. In this region, the line broadening is caused by the Doppler effect of the motions of the molecules, which is pressure independent. At high pressures the line width is proportional to pressure. This width is caused by the collisions of the gas molecules with each other, a process which disrupts the continuity of the absorption. This phenomenon is called collision broadening.

The following formula has been derived by

Van Vleck, and Weisskopf[9] for the absorption coefficients of spectral lines as a function of the line width as well as of many other factors affecting intensities:

$$\alpha = \frac{8\pi^3}{ck}\,\frac{n}{T}\,\frac{\nu^2}{\pi}\times \left\{\frac{\Delta\nu}{(\nu-\nu_0)^2+(\Delta\nu)^2}+\frac{\Delta\nu}{(\nu+\nu_0)^2+(\Delta\nu)^2}\right\}\times \frac{g_1\exp[-W/kT]}{pZ}u^2\left|\begin{matrix}J'\tau'M'\\ D\\ J\tau M\end{matrix}\right|^2$$

α = absorption coefficient in cm^{-1} at frequency ν
n = number of molecules per cc
ν = frequency of incident radiation
$\Delta\nu$ = half line width at half intensity points
ν_0 = center frequency of absorption
g_1 = weight factor which depends on the overall species of the two levels involved in the transition
W = average energy of the two levels involved in the transition
u = dipole moment of the molecule
$\left|\begin{matrix}J'\tau'M'\\ D\\ J\tau M\end{matrix}\right|^2$ = square of the direction cosine matrix element for the transition
c = velocity of light
k = Boltzmann constant
T = absolute temperature of the gas
p = symmetry number of the molecule
Z = rotational partition function for the molecule.

At low pressures, less than 1 mm., and at frequencies near the resonant frequencies of the lines, the second term in the brackets is negligible with respect to the first term. As peak absorption coefficients are more useful than those at other points, we let $\nu = \nu_0$ and obtain the following simplified formula for the peak absorption coefficient, α_0:

$$\alpha_0 = \frac{8\pi^3}{ck}\,\frac{n}{T}\,\frac{\nu_0^2}{\pi}\,\frac{1}{\Delta\nu}\times \frac{g_1\exp[-W/kT]}{pZ}u^2\left|\begin{matrix}J'\tau'M'\\ D\\ J\tau M\end{matrix}\right|^2$$

Significance of the Equation

The manner in which the absorption coefficient changes with variation in cell conditions and with different gases should be familiar to the analyst, because the coefficient is very important both in qualitative and quantitative analysis. The stronger the absorption by a molecule, the more readily it is detectable in small concentrations in a mixture of gases and the wider the range of concentration over which it can be determined quantitatively.

First consider the effects of changing the temperature and pressure of the gas in the cell. In the low pressure region, increasing the number of molecules per cc. in the cell, n, will increase the peak absorption coefficient. At higher pressures, the increase in $\Delta\nu$ nullifies the effect of increasing n, resulting in a constant peak absorption.

As both the exponential factor involving W and the partition function, Z, depend on temperature, as well as the T term in the denominator, the temperature dependence of the absorption coefficient is of high power and rather complicated. For linear molecules and symmetric top molecules in the lower rotational and ground vibrational states, suitable substitutions of values for W and for the partition functons lead to the following conclusions: the absorption varies inversely with the 5/2 power of the temperature for linear molecules, and inversely with the cube of the temperature for symmetric top molecules. Thus it can be seen that for accurate quantitative work, the temperature will have to be accurately known and controlled.

It seems very appropriate to consider the differences in the absorption coefficients of various molecules. When all other factors are equal, it is obvious that a gain in absorption is obtained by studying molecules having higher resonant frequencies, ν_0, because of the squared dependence on this variable. There is not space here to discuss the values of g_1 and p, except to remark that they are usually ratios of small whole numbers and that they do not give rise to wide variations in absorption from molecule to molecule.

If transitions are between two low lying levels, the exponential factor, $e^{-W/kT}$, is very close to unity and thus is essentially the same for transitions in different molecules involving low lying levels. Because of the square of the dipole moment, u, there is a decided advantage in studying molecules with large dipole moments; many hydrocarbons with their very small dipole moments will be very difficult to detect.

The factor $\left|\begin{matrix}J'\tau'M'\\ D\\ J\tau M\end{matrix}\right|$ is a function of various rotational quantum numbers, which will not be discussed; for the same transitions in different molecules, the factor is the same.

The partition function, Z, changes with the moments of inertia of the molecule, being larger for molecules with larger movements; thus, in general, a larger molecule has weaker absorptions because of its larger partition function. Very large hydrocarbon molecules will have weak absorptions both because of small dipole moments and because of large partition functions. The effect of the variation of the $\Delta\nu$ in Equation 2 for mixture will be considered in detail in the section on quantitative analysis.

Early Microwave Spectographs

The apparatus built by Cleeton and Williams[1], the first microwave spectrograph, resembled an infrared spectrograph to a certain extent because of the use of optical techniques in conducting the radiation. The source of radiation was different, however, as it was monochromatic, consisting of an electronic oscillator similar to the modern magnetron. The tube could be tuned 30 percent in frequency by varying the field, adjusting the plate voltage and filament current, and changing the angle between the filament and the field.

Because the source was monochromatic, a grating was not needed to obtain dispersion; however, a grating of 18 elements with a grating constant of 7.49 cm. was used to measure the frequency to within about one percent.

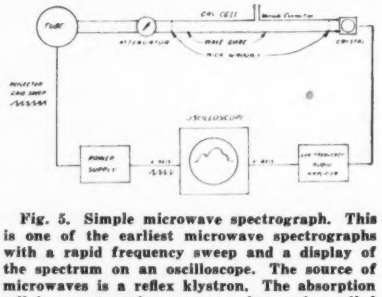

Fig. 5. Simple microwave spectrograph. This is one of the earliest microwave spectrographs with a rapid frequency sweep and a display of the spectrum on an oscilloscope. The source of microwaves is a reflex klystron. The absorption cell is a rectangular copper or brass pipe called a waveguide, from 5 to 100 feet in length. The half-circle trace on the oscilloscope, called a mode, is a plot of the power output of the tube vs. frequency. The small dip on the left side of the mode is an absorption line, which happens to be at the low point on a standing wave pattern in the waveguide. Most microwave absorptions are very weak. The wider less pronounced dip on the right side is caused by standing waves in the waveguide. Difficulty may be experienced in telling absorption lines from standing waves. The sensitivity of this apparatus is around 10^{-6} cm^{-1}.

Mirror, slits, and the grating were then employed in the same manner as in optical spectroscopy.

The detector, an iron-pyrite phosphor bronze crystal placed at the center of focus of a parabolic mirror, was connected to a milliammeter. The amount of microwave absorption was determined by the change of the milliammeter reading when a rubber bag filled with ammonia was put between two parabolic mirrors directing the microwave energy. The chief disadvantages of this apparatus were its lack of resolution and poor sensitivity.

Direct-Absorption Sweep-Frequency Spectrograph

One of the earliest high resolution spectrographs is the direct absorption instrument outlined in Fig. 5. The radiation source is a reflex klystron —for example, a QK-33 from 20,000 to 26,000 mc. As the d-c. voltage on the reflector grid of one of these tubes is varied over a range of several hundred volts, there will be several regions in which the tube will oscillate and somewhat larger regions in which the tube is inoperative. The microwave frequency in an individual oscillating region, called a *mode*, changes with the voltage, being of the order of 50 mc. lower on the low voltage end than at the high voltage end of the mode.

A saw-tooth voltage applied to the reflector grid along with a large d-c. voltage will thus sweep the tube over a small portion of the spectrum at a rate determined by the frequency of the saw-tooth voltage. A mode of the tube is the half-circle displayed on the oscilloscope of Fig. 5, but without the irregularities. In this picture the deflection above the horizontal line gives the intensity of the radiation from the klystron, whereas the position along the horizontal axis gives the frequency.

In this sweep frequency spectrograph, the amplitude of the saw-tooth voltage can be varied to change the magnitude of the spectral region viewed per sweep. To change the frequency of the mode, the knob on the tube is turned. The usual reflex klystron can be tuned over several thousand megacycles.

The radiation in this and other modern microwave spectrographs is propagated through rectangular copper or brass pipes called waveguides. The absorption cell consists of a piece of waveguide vacuum tight at the ends with mica windows. The rectified crystal output is amplified by a low frequency audio amplifier and displayed on the oscilloscope. At low pressures, around 10^{-1} to 10^{-3} mm. mercury, a strong absorption is displayed as a small dip in the mode as seen to the left of the center of the mode in Fig. 5.

The wider, smoother dip on the right side is caused by standing waves in the waveguide system. As it has a very limited sensitivity, about 10^{-6} $cm.^{-1}$, this spectrograph will not detect the absorptions by many molecules. Its chief advantages are its simplicity and its resolution, which is as good as that of any other microwave spectrograph. Line widths of only 0.05 mc. have been observed under suitable conditions.

The Stark-Effect Microwave Spectrograph

The Stark-effect microwave spectrograph is discussed in detail here because of its good sensitivity and the

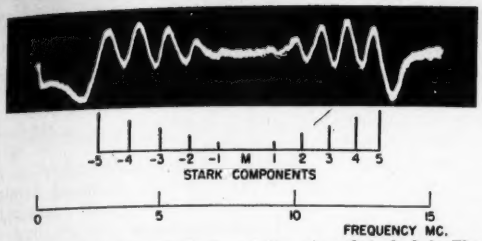

Fig. 6. Stark-effect of the J = 5 line of methyl alcohol. The spectrum was obtained useing the spectrograph of Figure 7 with sine wave modulation. Stark fields of 50 volts/cm. d-c. and 1 volt/cm. a-c. at 85 kc. were applied. The large d-c. voltage splits the original single line up into a large number of components, the positions of which are indicated in the plot below the photograph. The small a-c. field at 85 kc. moves the components a small distance at a frequency of 85 kc. causing modulation of the microwaves at 85 kc. The amplified and detected modulation is shown in the photograph. This detection system gives approximately the first derivative of the line shape of a component. Unfortunately, it was not possible to completely separate the components and still observe the entire set simultaneously.

Fig. 8. The Westinghouse Stark-effect microwave spectrograph. A first order line of methyl alcohol in a field of 1 volt per cm d-c. and 1.4 volts per cm. a-c. sine wave is displayed on the trace of the oscilloscope. The microwave source, a reflex klystron, is shown in the center of the picture. Two cables lead to its power supply under the oscilloscope. The microwave energy after passing through the tee at the back of the table passes through a tapered section into the larger waveguide of the cell. The Stark-effect cell is made from 20 feet of X band waveguide and is supported by strings from the 2 by 4 seen at the left of the picture. An insulated trough surrounds the cell to hold dry ice for low temperature measurements. Part of the vacuum system for handling the samples is seen at the left edge of the picture.

elimination of most of the standing wave interferences found in the simple spectrograph. The Stark-effect refers to the action of an electric field on an absorption line; the applied electric field interacts with the electric dipole of the molecule to change the energy of the rotating molecule.

On the application of an electric field which is gradually increased in intensity, the first effect observed is a widening and smearing of the line. At greater field intensities, the line starts to split up into components and at sufficient field strength is entirely resolved into its components as shown in Fig. 6. The various components, labeled with the allowed values of the quantum number M, arise because the molecule can assume different positions with respect to the applied field which have various discrete values of electrostatic energy.

The deviation of a component from the original line frequency is proportional to EM for symmetric rotors and proportional to E^2M^2 for linear molecules, where E is the field gradient in the cell. The intensities of the various components are not all the same, but depend upon transition probabilities as calculated from quantum mechanics.

A block diagram of the Stark-effect microwave spectrograph is shown in Fig. 7. The basic principle of this equipment is the modulation of an absorption line by the application of a low frequency field to the gas to give an alternating Stark-effect. In the vicinity of an absorption line, the microwave energy leaving the absorption cell is modulated. After the signal from the absorption cell is rectified by a silicon crystal, it is amplified and detected by a narrow band radio receiver.

The receiver output is viewed on the vertical axis of an oscilloscope, while the horizontal deflection is performed by a saw-tooth voltage sweeping the microwave tube through a small portion of the spectrum. The spectrum observed is considerably more complicated than that given by the simpler spectrograph, but, on the other hand more information is displayed.

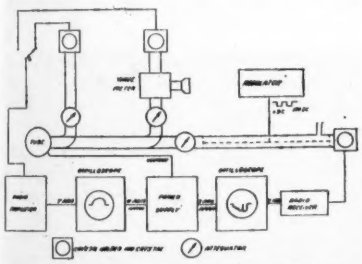

Fig. 7. Block diagram of the Stark-effect microwave spectrograph. The mode of the microwave source, a reflex klystron, is shown on the left oscilloscope. The gas sample is contained in the cell of Figure 9. A 100 kc. square wave voltage with one side based on zero voltage is applied to the Stark electrode. Sine wave modulation can be used instead of the square wave. The big dip on the right oscilloscope is the absorption at the original line frequency. The three overlapping dips to the left are three Stark components which have not been entirely resolved. Standing waves are not seen on this spectrograph. The sensitivity of this instrument is around 10^{-8} cm^{-1}. With the use of a recorder the sensitivity approaches 10^{-9} $cm.^{-1}$.

Construction of Stark-Effect Spectrograph

A picture of the spectrograph is seen in Fig. 8. The source of energy is the reflex klystron, various models of which are now available to cover the region from 1,000 mc. to 60,000 mc; the spectrum between 20,000 and 60,000 mc. has been most commonly employed in spectroscopy. The two side arms to the right of the tube (see Fig. 7) remove energy for monitoring the mode and for measuring the frequency. The wavemeter in the drawing is a transmission type meter, which can be used for rough frequency measurements.

The absorption cell for the gas, the cross-section of which is shown in Fig. 9, consists of a standard size waveguide with a flat brass or bronze strip as electrode, supported in the center of the guide by slotted pieces of polystyrene or teflon. An electrical connection is made to the electrode by a wire extending through the side of the guide and into a Kovar tube soldered on the guide's small side and glass-sealed.

The modulator is shown in Fig. 7 as having a square wave output voltage of 100 kc.; the voltage needed varies with the molecule, the range being from less than one volt up to several thousand volts. As the pressures normally employed in the cell range from 10^{-1} to 10^{-4} mm., only a moderately good vacuum system is needed; a small, two-liter, single stage, oil diffusion pump works satisfactorily even when backed by only a single stage Welch mechanical pump.

A typical oscilloscope pattern is shown in the right oscilloscope screen of Fig. 7. This pattern taken with square wave modulation with one side based on zero is very easy to interpret; the big dip on the right represents the absorption at the undisplaced line position, whereas the three dips on the left are caused by the three Stark components of the absorption line.

When a still stronger voltage is applied, the dip on the right remains at the same position, while the three components which now overlap move further to the left and become completely resolved. The sine wave modulation employed in Fig. 6 and 8 distorts the line shape, but gives pictures which can easily be interpreted when proper voltages are used. A sine wave modulator is much simpler and less expensive to construct than a square wave generator.

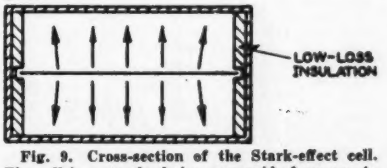

Fig. 9. Cross-section of the Stark-effect cell. The cell is a standard size waveguide from one to forty feet long. A flat strip of brass or copper is supported in the center of the guide to serve as an electrode. The insulation supporting the electrode is usually polystyrene or teflon. The arrows indicate the direction and magnitude of a static electric field. Mica windows at each end of the cell make it gas-tight.

More details on the construction and operation of the Stark-effect spectrograph will be found in references 10 and 11.

Frequency Measurements

Rough measurements of frequency, about ± 10 mc., can be obtained with a calibrated wavemeter. Much more accurate measurements can be obtained by electronic means. The following is a description of the frequency measuring equipment now in use at the Westinghouse Research Laboratories. A block diagram is shown in Fig. 10 and a picture in Fig. 11.

The frequency of the primary oscillator, a five-mc. crystal stabilized oscillator, is adjusted to within one cycle of the five-mc. broadcast of WWV. After multiplication to 500 mc. by a series of electronic frequency multipliers, the signal is fed into a crystal where harmonics of the 500 mc. are generated throughout the microwave frequencies.

A radio receiver is used to detect the beat note between these harmonics and the microwave energy fed into the crystal from the klystron; a pulse is obtained when the difference between a harmonic and the microwave frequency is equal to the receiver setting. Two pulses are obtained for each harmonic, one when the microwave frequency is below the harmonic by the amount of the receiver setting; the other, when the microwave frequency is above by the same amount.

A 50 mc. signal is fed into the mixing crystal to give other sets of pulses, called *markers*, at 50 mc. intervals throughout the spectral region. When a frequency is being measured, the receiver is tuned so as to set a marker on the point on the line to be measured. A wavemeter reading will determine which set of frequency markers is being used.

The receiver reading is then added or subtracted from the center frequency of the pair of markers according to whether the high frequency or the low frequency marker has been used. The frequency of a strong line can be determined to within about ± 0.02 mc. by this method with an accurately calibrated receiver, the limit of the accuracy being caused by the width of the line. Details of similar frequency standards are given in references 12 and 13.

Qualitative Analysis

Several important factors which determine the suitability of spectrographic instruments are the following: (1) the number of separate identifiable lines in the spectral region, (2) the precision with which their frequencies can be determined, (3) the minimum detectable concentration, and (4) the size of the sample required. In this section the suitability of the microwave spectrograph for qualitative analysis as determined by these factors is discussed.

The number of possible separate identifiable lines in the microwave region is very great. This number is determined both by the region of the spectrum available to the spectrographer and by the widths of the lines. Kisliuk and Townes of Columbia University[14] in their tabulation of microwave spectral lines choose to let 1,000 mc. be the lower limit of the microwave spectrum.

The upper frequency limit is that of the highest frequency, continuous wave, electronic tubes—around 200,000 mc. at the present time. As under the conditions of best resolution line widths are around 0.2 mc., about 1,000,000 separate lines could be placed in this region without overlapping. With the accurate frequency measuring equipment that the microwave spectroscopist employs, it would be possible to identify each of these lines by frequency measurements.

Even if only the range covered by a single QK-33 were available (20,000 to 26,000 mc.), 30,000 separate lines could be measured and identified. This is much greater than the 3,000 lines for the infrared under the assumption of a range of 3,000 cm.$^{-1}$ with an average resolution of 1 cm.$^{-1}$. One advantage of microwave spectroscopy is that lines can be listed in tables instead of requiring absorption plots as in the infrared.

Identification of Compounds

Because of this high resolution and precision of measurement of frequencies, the identification of a compound by the measurement of one line frequency, or at the most two, should be possible. The compilation of microwave spectroscopy lines by Kisliuk and Townes[14] shows very few near coincidences in line frequency for 30 substances, most of the lines being several megacycles apart. If the measurement of the frequency of one line leaves doubt, a count of the components of the line after splitting with the use of a high Stark voltage should definitely identify the substance. If there is still some doubt, the measurement of the magnitude of the Stark-effect will surely remove any ambiguity.

Sensitivity

The relationship between the sensitivity of the apparatus and the intensity of the absorption lines is of importance in both qualitative and quantitative analysis. As the average absorption coefficient is around 10^{-6} or 10^{-7} cm.$^{-1}$, the intensity of the radiation would be reduced to 40 percent of its original value in traversing a cell from 10 to 100 kilometers long. An absorption coefficient of one cm.$^{-1}$ corresponds to the reduction of the intensity of radiation on passing through one centimeter of the material to $1/e$ of its value on entering the sample.

In the usual cell, between 5 to 20 feet long, the resultant absorption is very small. The weakest lines detected in microwave spectroscopy have an absorption coefficient around 10^{-9} cm.$^{-1}$, which means that the radiation would be reduced to half intensity in a cell which goes quarter way around the world. Thus, there is a range of 100 to 1,000 between the average intensity of most substances and the minimum de-

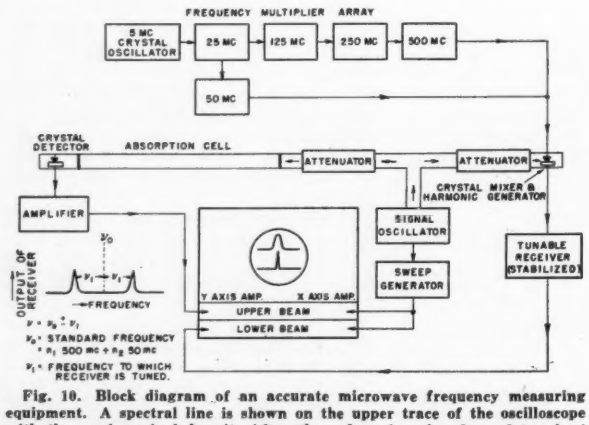

Fig. 10. Block diagram of an accurate microwave frequency measuring equipment. A spectral line is shown on the upper trace of the oscilloscope with the marker pip below it. After the value of ν_0 has been determined by a wave meter, the receiver reading is added or subtracted, according to whether the left or right pip is being used. Frequencies can be determined to within ±0.1 mc or less in the range between 20,000 and 40,000 mc. The accuracy is usually limited by the width of the spectral lines.

Fig. 11. The Westinghouse microwave frequency measuring apparatus. The chassis on the left of the table is the receiver for the 5 mc. WWV standard frequency broadcast. The beat note between the WWV signal and the output of the 5 mc. crystal oscillator is observed on the magic eye on top of the receiver. The 5 mc. crystal is in a thermostated oven, the large can on the second chassis. The 25 mc. output from the second chassis is multiplied to 500 mc. in the third chassis. The last amplifier to the right gives the 50 mc. signal for the added reference frequencies. The harmonic generator and mixer, a silicon crystal, is shown in its holder above the waveguide. The receiver for the interpolation, shown in the lower right-hand corner, is a Collins 51J which measures frequencies to within ± 2 kc. over the range from 0.5 to 30.5 mc.

tectable absorption with present equipment.

Difficulty will be experienced, therefore, in detecting many constituents when their concentration is below one per cent in a mixture; further developments in equipment should improve this situation. There are many substances, however, which do have large absorptions; an example is ammonia with a coefficient greater than 10^{-4} $cm.^{-1}$, which could be detected if only one part in 10^5 were present in the sample.

Small-Sized Sample Required

One distinct advantage of the microwave spectrograph is the small size of sample required. As the cell does not require more than about 10^{-7} moles of gas to fill it to the usually employed pressure, the sample is much less than that required in most infrared spectrographs. Of course, much smaller amounts than this of substances with strong absorption coefficients can be detected.

An advantage of spectroscopy over ordinary chemical analysis is the nondestructive effect of the radiation. The sample is usually not recovered during most studies because plenty of sample is available. In certain microanalytical problems, however, recovery may be desirable.

Microwave Spectral Data

The compilation of microwave spectral lines prepared by Kisliuk and Townes[14] of Columbia University, acting as a consultant with the National Bureau of Standards, contains all the spectral lines which had been reported in the literature up to 1949 and some information obtained by private correspondence. It lists about 600 lines for 30 different substances; identifications of transitions are given when known.

Calculated intensities are given for symmetric tops and linear molecules for which the dipole moments are known. These intensities may be in error for molecules for which the line widths had not been measured and had to be estimated. As the original table is becoming obsolete, a supplementary table was published in May, 1950. The National Bureau of Standards plans to take over the compilation of microwave absorption data and to publish tables for general distribution, which should be very helpful to the analyst.

Quantitative Analysis

The two major problems in quantitative analysis with a spectrograph are the measurement of absorption coefficients and the correlation of these measured coefficients with the composition of the mixture. First, a discussion is given below of what is known at present about the correlation of intensities with the composition of mixtures; the instrumental problems in connection with intensity measurements with the microwave spectrograph are then discussed.

Lambert's law, $I/I_0 = e^{-al}$, seems to be obeyed under most conditions in microwave spectroscopy. I is the intensity of radiation leaving the cell; I_0 is the intensity entering the cell; a is the absorption coefficient per unit length, and l is the length of the cell. The amount of energy absorbed in a unit thickness of cell is proportional to the amount of energy entering the cell.

The only known reason for this law not holding is the power saturation effect. A large intensity of radiation may disturb the normal thermal distribution of molecules in the various rotational states. As under these conditions the line shape changes along the cell, there will be no simple relation

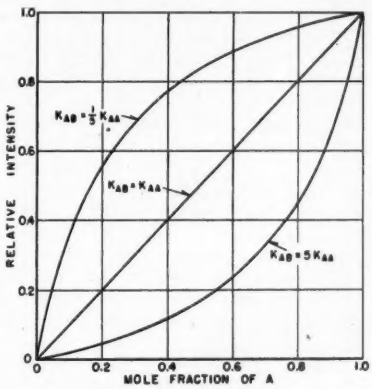

Fig. 12. Peak absorption coefficient for line of constituent A in a binary mixture. K_{AA} is the collision broadening parameter of molecule A for A; K_{AB} is the collision broadening parameter of molecule B for A. Measurements of peak absorption coefficients will probably be used for quantitative analysis. The peak absorption coefficient is, in general, not a linear function of the composition of the mixture. At low concentrations, the coefficient is approximately proportional to the concentration of constituent giving rise to the absorption. At very high concentrations the dependence is still linear but the absorption coefficient is not directly proportional to the concentration.

between the amount of absorption and the length of the cell.

Two types of coefficients may be measured for quantitative analysis: peak absorption coefficients and integrated absorption coefficients. Peak coefficients, at least for pure substances, have the advantage of being rather independent of the pressure in the gas cell over a wide pressure range. On the other hand, the coefficients can be integrated over the whole line to give the line intensity, which is proportional to the partial pressure of the gas in the cell. As the use of peak absorption coefficients would seem to involve fewer measurements, their use is discussed in the following discussion of quantitative analysis.

Significance of Peak Absorption Coefficient

The value of the peak absorption coefficient in a pure gas can be calculated using Equation 2. For a stated gas at a given temperature and for a given transition that equation simplifies to the following simple expression:

$$a_o = Kp/\Delta v, \text{ where} \qquad (3)$$

K = a constant
p = pressure of gas in cell
Δv = half line width at half intensity points.

In the constant coefficient region, Δv is proportional to the pressure.

The calculation of the peak absorption coefficient as a function of the concentration of the unknown in a mixture of varied constitutents is in general more complicated. In the ideal case, Δv is proportional to the total pressure of the gas in the cell and thus a_o is proportional to the mole fraction of the unknown in the mixture. Under these conditions Beer's law in the following form holds:

$$\text{Log } I/I_o = kX, \text{ where} \qquad (4)$$

k = a constant
X = mole fraction of constituent in mixture

Unfortunately, however, this law is not generally applicable. Because a foreign substance may have a different collision broadening effect with respect to the molecules of the material being studied than do the molecules of the material for themselves, the line widths change with composition for the same total pressure. Then the maximum absorption coefficient of an absorption line will no longer be proportional to the mole fraction of the unknown in the mixture.

An example of the failure of Beer's law for this reason occurs in mixtures of ammonia gas and argon. When an ammonia sample is diluted with argon so that the resultant mixture is only five per cent ammonia, the height of the ammonia line decreases to only half that for pure ammonia. The collision cross-section of ammonia for ammonia is several times greater than that of argon for ammonia.

Formulas will now be derived for the peak absorption coefficient of a substance in a two component mixture on the assumption that

$$\Delta v = k_{AA}p_A + k_{AB}p_B$$

k_{AA} = collision broadening factor of the molecules of material A, the constituent being determined, for themselves
k_{AB} = collision broadening factor of the molecules of material B for those of A.

The first formula will be for the case that the desired consitituent is present in low concentrations and the second formula for the case that the desired constituent is the major constituent. Substitution in Equation 3 under the conditions that $k_{AA}p_A << k_{AB}p_B$ and simplification gives for the condition that A is present in very small concentrations:

$$a_{oA} = KX_A/k_{AB}, \text{ where} \qquad (5)$$

X_A = mole fraction of A in mixture.

It will be noted that at the low concentrations, where this approximation is justified, the peak absorption coefficient is proportional to the concentration of the desired constituent, but that the slope of the concentration curve depends on the collision broadening factor of the diluent for the desired constituent. When the desired constituent is the main component of the mixture, making use of the fact that $k_{AA}p_A >> k_{AB}p_B$ and simplifying after substituting in Equation 3 gives:

$$a_{oA} = K/k_{AA}[1-(k_{AB}/k_{AA})\ 1\text{-}X_A)]$$

It is to be noted that in this case, the peak absorption coefficient is a linear function of the mole fraction of constituent A; however, it is not directly proportional to the mole fraction unless $k_{AA} = k_{AB}$. Fig. 12 shows the results which should be expected on studying two component mixtures over the entire concentration range for different ratios of k_{AA} to k_{AB}.

Multicomponent mixtures would be very easy to analyze in microwave spectroscopy if it were not for these broadening effects. As the absorptions do not overlap, it would not be necessary to solve simultaneous equations because of overlap, as is reqiured in infrared spectroscopy. It will probably be expedient to use working curves for many mixtures because of the changes in line broadening effects with concentration.

One method of avoiding the broadening problem while making peak absorption coefficient measurements is to add a large concentration of a diluent as a broadening agent. If the diluent is then the major constituent of the mixture, the broadening effects will be well defined and can be taken into account by studying mixtures of unknowns and the diluent. The disadvantage of this method is that the peak absorption coefficients are reduced on dilution so that accuracy may be lost and lines of substances with weak

absorptions may be missed. This attack may be fruitful, however, with substances with strong absorption coefficients, such as ammonia and hydrocyanic acid.

Intensity Measurements

The instrumental problems in connection with the measurement of absorption coefficients in the microwave region have not all been satisfactorily solved; these measurements are very difficult. The most accurate measurements up to the present time have been done with modifications of the simple spectrograph in Fig. 5. The measurement of absolute absorption coefficients with these spectrographs is discussed by Good[15] and by Townes[16]; they obtained an accuracy of about ±10 percent for the ammonia lines.

Absolute absorption measurements have not been satisfactorily made with the Stark-effect spectrograph. As relative measurements can be made with a fair degree of accuracy with the Stark-effect spectrograph, quantitative analysis by comparison with known samples should be feasible. It seems reasonable that a program of intensive development by a group primarily interested in analysis and quantitative absorption studies should lead to the solution of these problems in the microwave region.

High Speed Observation

The rapidity with which a small portion of the spectrum can be scanned should be very useful in chemical reaction studies. As under certain conditions a line or a close group of lines can be observed as rapidly as 60 times a second, changes in intensity can be followed very rapidly.

An interesting application of the rapid sweep occurred during the study of the microwave spectrum of ozone; the lines were found to decrease to half intensity in about 30 seconds. This decomposition in the waveguide is much more rapid than that ocurring at higher pressures in a glass vessel, where the decomposition rate is around 5 to 10 percent per hour.

Summary of Advantages and Limitations

The following advantages of microwave spectroscopy seem to be evident from the present knowledge of the subject. About 100,000 separate lines could be crowded into the region between 20,000 and 40,000 mc. without overlapping. Because of the very accurate frequency measurements now possible, all of these lines can be identified as to frequency without ambiguity. Microwave spectral lines can be listed in tables as numbers instead of being given as bands on graphs.

Identifications of chemical substances can be accomplished by measuring the frequency of one line and perhaps checking by measuring the frequency of a second line. As isotopes change the frequencies of microwave lines so appreciably as to give new lines widely separated from those of the original substance, this spectroscopy should be very important in analysis of isotopic mixtures.

Samples of the order of magnitude of 10^{-6} g. are required—smaller than that needed in most infrared spectrographs. As the rapidity of observation of small regions of the spectrum can be increased so that many observations can be taken each second, microwave spectroscopy could be used to study fast chemical reactions. The cost of the equipment may be less than that of a good infrared spectrograph.

Microwave spectroscopy has several disadvantages. The requirement of a permanent dipole moment will exclude the study of certain symmetrical compounds and many hydrocarbons of small or zero dipole moment. The necessity of having a vapor, even with a limited vapor pressure of 10^{-3} mm., eliminates many nonvolatile inorganic substances.

In spite of the fact that the equipment is very sensitive, the weakness of absorptions in rotational spectra limits the usefulness of the equipment; infrared has the advantage of stronger absorptions in many cases. As the absorptions become weaker for heavy molecules because of a large partition function, Z, sensitivity difficulties may be experienced in working with very heavy molecules. Although the equipment is rather complicated at present, further development may simplify it.

There are several specific problems which need to be solved before the microwave spectrograph will be a generally useful analytical instrument. The spectra of many more substances must be studied and their lines listed in tables before the instrument will be of general utility in detecting substances qualitatively. The techniques of measuring absorption coefficients or line intensities with the sensitive modulation spectrographs must be developed for quantitative analysis. As the present Stark-effect cells with the plastic insulation tend to absorb many organic materials, some cell development should be undertaken.

It appears that many analytical problems could be solved with microwave spectroscopy. This new tool will become more useful as more developments are made in the field.

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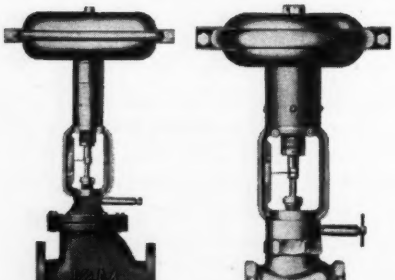

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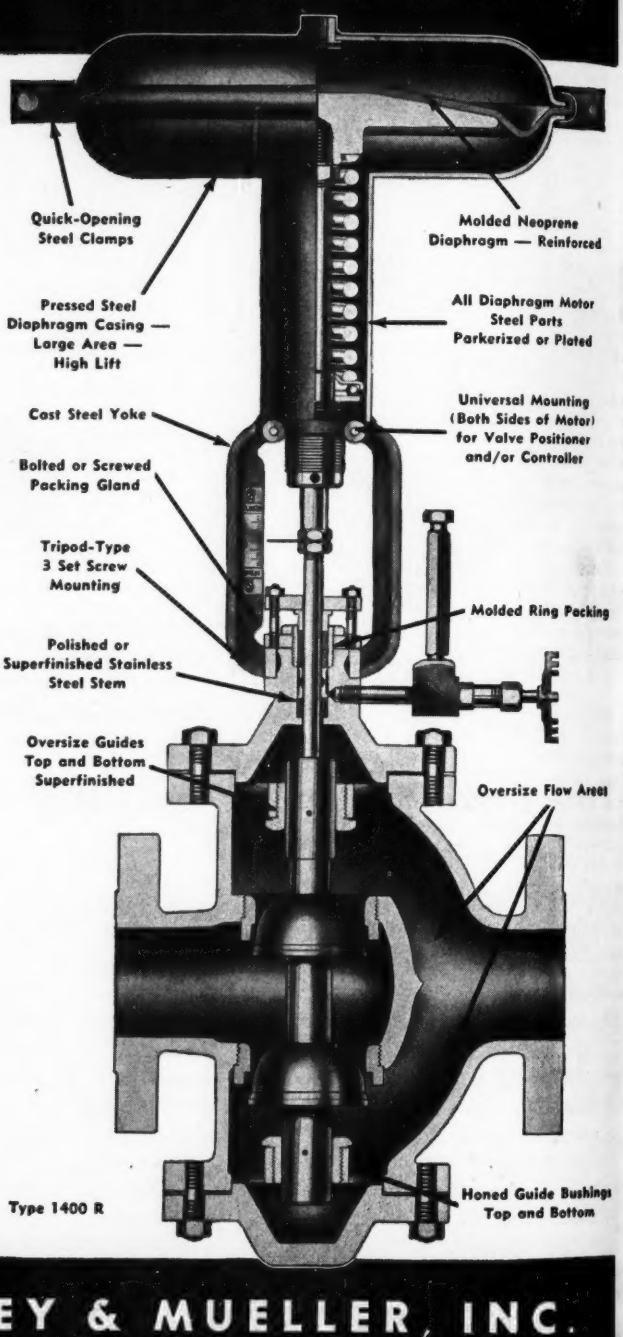
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The Noise Problem *at* Regulator Stations

By F. M. PARTRIDGE, Southern California Gas Company

FOR many years the acoustic noise associated with the operation of pressure regulators has been a problem at regulator stations. With the advent of long transmission lines, which often terminate at relatively large measurement and regulation stations in populated areas, the noise problem has become acute. The reduction of noise from regulators has been accomplished in several different ways; it is the purpose of this article to discuss some of the methods used and to point out their relative merits.

Noise can be defined as any sound which has no definite pitch, or which is disturbing to persons who hear it. In order to study noise it is necessary to measure its intensity and its frequency.

Decibels

Sound intensities usually are expressed in decibels (db). The decibel is the smallest change in sound intensity that can be detected by the average ear. As the ear responds to ratio changes in intensity (the louder the sound, the more it must change before the ear can detect the change), a sound intensity in decibels is defined as the ratio of the sound to one of zero-decibel (0-db) intensity. The standard reference-level signal of 0-db intensity has been agreed upon by sound engineers as one with a power of 0.0002 dynes per sq. cm. at a frequency of 1,000 cps. This sound was arbitrarily agreed upon because it is the weakest 1,000-cps. sound that can be heard by a person with good hearing.

The formula for the intensity (or power) of a sound in decibels is:

$$Decibels = 10\ log_{10}(P/P_0),$$

where P is the power of the sound, and P_0 is the power of the reference-level sound (0.0002 dynes/sq.cm.).

As sound power is proportional to the square of sound pressure, the formula becomes:

$$Decibels = 20\ log_{10}(E/E_0),$$

where E and E_0 are the sound and reference-sound pressures, respectively.

As the decibel is a logarithm, addition of decibels is equivalent to multiplication of pressures or powers. A few interesting facts about sounds expressed in decibels are as follows:

1. Doubling sound power is equal to an increase of about 3 db, so that when two equal sounds are added together, regardless of their actual value, the resulting sound level is 3 db. higher than one of the sounds alone.

2. If you add a 40-db sound to a 50-db sound, the result is a 50.4-db sound, or a negligible increase.

3. If a sound is 10 db (or more) *lower* than the background level, it is inaudible and of no importance.

The sound levels of a number of common noises are listed in Table 1 to illustrate the meaning of sound levels expressed in decibels. The threshold of feeling is about 120 db. The average threshold of hearing is 0 db for a 1,000-cps. tone and about 20 db for the rustle of leaves.

TABLE I—TYPICAL SOUND LEVELS

Decibels	*Sound*
140	Airplane motor test chamber
130	Pneumatic rock drill
125	Airplane motor at 20 feet
120	Auto horn, thunder, artillery
110	Boiler factory
100	Elevated train overhead
90	Heavy city street traffic
80	Police whistle, noisy office
70	Automobile passing
60	Conversation
50	Average office
40	Quiet office
30	Broadcast studio
20	Rustle of leaves
0	Weakest 1,000-cps. tone detectable by ear

Frequency Response of the Ear

The response of the ear to sounds of different frequency is shown in Fig. 1, which has a number of Fletcher-Munson equal-loudness contours. Each curve is made by plotting the intensity of a sound of a given frequency which appears to be as loud as a reference sound of 1,000-cps. tone. Thus the zero equal-loudness contour contains all sounds which appear to be the same intensity as a 0-db 1,000-cps. tone.

Fig. 1 describes the boundaries of auditory sensation. The region which we use for speech is shown by one of the shaded areas. This is the level at which we like to hear things. It is the level to which we adjust our radios and the level in the average movie theatre. It can be noted that seldom in nature is there a noise which extends above this level. When such sounds do occur they usually are associated with terrifying phenomena such as thunder.

Note that the frequency is important in determining the disturbing effect of a sound.

Distance

The distance from the sound source to the point of hearing is important in determining what constitutes objectionable noise. In general, the level decreases 6 db each time the distance from a sound source is doubled. For example, if a regulator created a sound level of 100 db at a distance of two feet, the sound level at four feet would be 6 db less, or 94 db. Fig. 2 shows how the sound level decreases with increased distance from the source—provided that there is no wind or other air movement. This curve can be applied to other conditions by drawing a line parallel to the one shown through a known point for the given conditions. Any insulation other than air, such as walls, earth, or building, further decreases the sound level as the distance to the sound source increases.

Instrumentation

The sound-intensity level of a noise can be measured by a *sound level meter*, which indicates sound level in decibels. This value is absolute and can be used as a standard for comparison at any location and with any noise source.

The pitch, or frequency, of the sound is often as important as the sound level in determining whether a given sound should be classed as objectionable or not. The intensity of the components of a sound at various frequencies can be determined by means of a *sound analyzer* connected to the sound level meter. From the results obtained a characteristic curve can be plotted on logarithmic paper (like the curves in Fig. 1) and a decision made as to how

Presented before the SCMA, May 17, 1951.

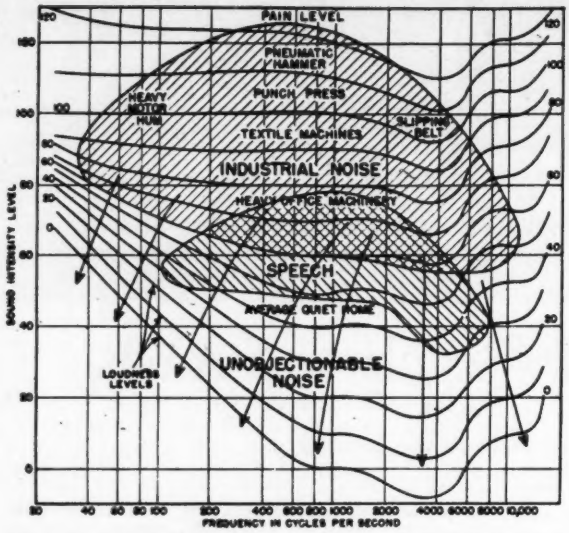


Fig. 1. General ranges of speech and industrial noises. ("Control of Noise in Mechanical Equipment" by Howard C. Hardy)

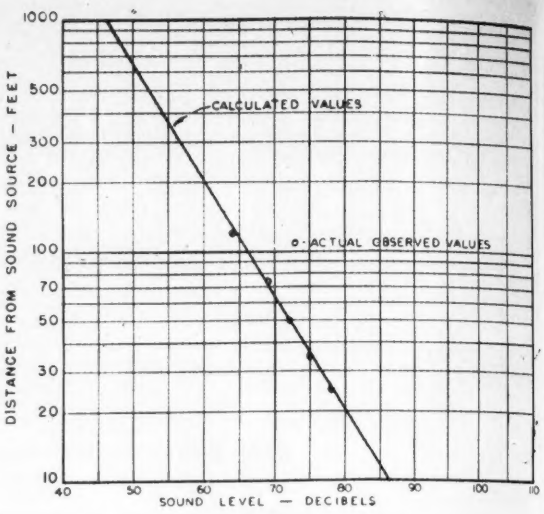


Fig. 2. Curve of sound level vs. distance from source.

objectionable the noise is. Fig. 3 shows a typical sound level meter and sound analyzer.

Methods for Reducing Noise

The general methods for reducing objectionable noise levels at pressure-regulation stations are as follows:

1. Regulator noise usually can be reduced by applying earth, sand, concrete, etc., to the vibrating surface. The earth increases the mass of the vibrator and acts as a dampener. The use of common acoustical surface absorbents is not effective except for the absorption of the sound after it has been radiated. In one station where the sound level was abnormally high, the loudest sound apparently came from a 30-in. header in a concrete trench. In an attempt to dampen the vibration and decrease the noise level, the trench was filled with water. As the water did not have enough resistance to deformation, it had practically no effect on either the noise or the sound level. The trench was later filled with sand, which was effective in reducing the vibration to a satisfactory level.

2. Insulation can be placed as a discontinuity in the transmission path. For air, some type of sound shield, such as a wall or partition, can be used. To control sound transmitted through piping, ventilating ducts, or other solid path, the use of felt, cork, rubber, springs, etc., is recommended as a sound insulator. This insulation should be placed as close to the source of sound as possible.

3. Some type of sound absorbent material can be installed on exposed surfaces. This type of control is almost always accomplished by applying one of the standard acoustical surface absorbents to the walls, ceilings, and floors surrounding the listening position. The purpose of this is to improve conditions for those who maintain the regulators and equipment.

Reduction of air-borne noise must be done by walls or partitions which are large in comparison with the wavelength of the sounds whose transmission is to be impeded. Wavelengths of common sounds vary with the frequency. The wavelength at 7500 cycles is 0.15 ft.; the wavelength at 500 cycles

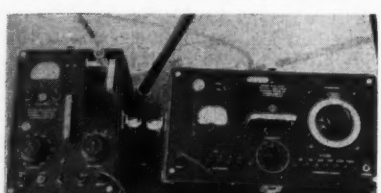


Fig. 3. Sound level meter and sound analyzer.

is 2.25 ft. Sound transmission through walls can be reduced by applying various insulating materials and by providing dead air spaces.

Sound transmission loss in decibels for various partitions varies from 18.5 db for 0.2 inch of wood to 59 db for a double 2-in. solid gypsum tile wall, the two sections of which are completely isolated structurally by a 4-in. air space.

Vault-cover Insulation

Probably one of the most common expedients, when a complaint of objectionable noise from an underground regulator station is received, is to apply some sort of insulation to the vault cover. There are many materials that can be used, and the results obtained vary widely in effectiveness.

A test was conducted to determine the efficiency of one especially designed insulated cover which was installed on a vault containing an 8-in. balanced valve regulator which had been the source of objectionable noise. The cover consisted of 20 Ga. sheet aluminum top (for protection from weather) over ½-inch Simpson Roof Insulation Board, 4 inches of Fiberglass with 2 x 4 in. Simpson Board frame, and ⅛-in. Masonite Tempered Presdwood Perforated for a bottom covering. This cover was not designed for traffic loads but could be used in fenced areas or as an inner cover on standard vaults. Some method of sealing must be provided to prevent sound leakage around the edges of the cover.

Simultaneous readings of sound levels inside the vault and on top of the vault were recorded as the flow through the station was gradually increased from 0 to 3,000 M.C.F. per hour. With a pressure drop across the regulator of approximately 130 psi., the sound level inside the vault increased 40 db while on top of the vault the increase was only 3 db when the flow rate was increased. Curves showing the variation in sound levels inside and outside of the vault as the flow rate varied are shown in Fig. 4.

Piping

An inexpensive and convenient method that can be applied readily to reduce sound emanating from piping is to cover the piping with earth or sand. At one regulator station, comparative sound levels were obtained first with the pipe exposed, then with the piping buried with 4-in. cover of sand, and finally with some of the sand removed so that the top of the pipe was exposed. The sound levels under similar conditions of flow varied from 106 db for exposed pipe to 86 db when the pipe was covered and to 92 db when the top of the pipe was exposed. The condition of the pipe under the various conditions, and a comparison of the various sound levels are shown in Fig. 5.

The station finally was finished with approximately 4 inches of cover over the meter tubes and piping, and boxes were built around orifice fittings, regulators, and valves. A thin layer of

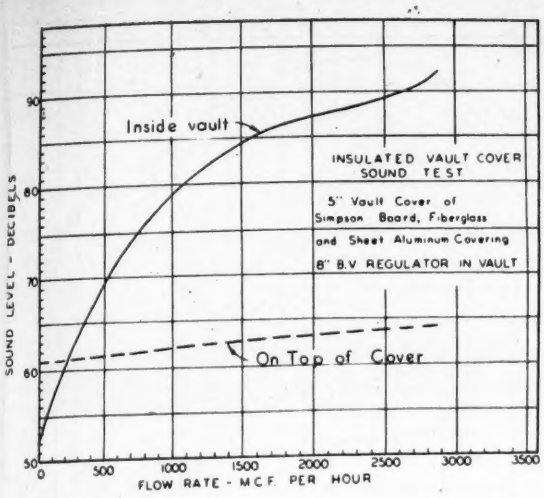
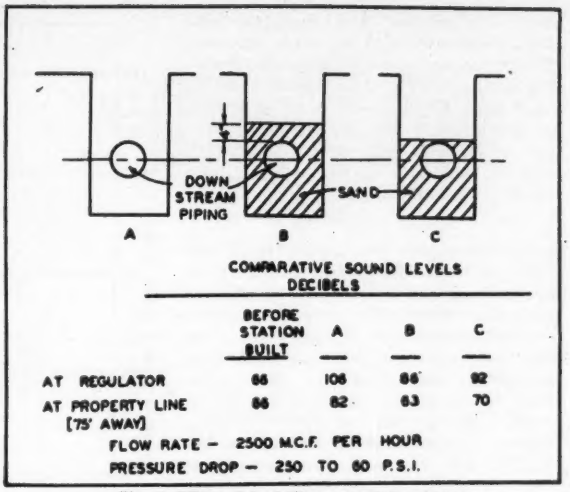


Fig. 4. Efficiency of an insulated vault cover.



COMPARATIVE SOUND LEVELS
DECIBELS

	BEFORE STATION BUILT	A	B	C
AT REGULATOR	86	106	86	92
AT PROPERTY LINE (75' AWAY)	86	82	83	70

FLOW RATE — 2500 M.C.F. PER HOUR
PRESSURE DROP — 250 TO 60 P.S.I.

Fig. 5. Effect of backfill on sound from pipes.

black top was placed to provide a better appearance and to keep the sand cover in place. Fig. 6 shows the station meters. The details of the boxes and sand cover of the regulator bodies are shown in Fig. 7.

Sand is more desirable than most types of earth as a sound insulator or absorber because it contains considerable air space and tends to stay in close contact with vibrating piping. Many types of earth, on the other hand, have a tendency to pack, and voids are created by the piping vibration.

Some data was obtained on the transmission of sound through buried pipeline from one vault downstream through 150 feet of 20-in pipe to another vault. The sound reduction was greatest at the higher sound levels. The reduction varied from 28 db (when the upstream sound level was 100 db) to 23 db (when the upstream level was 89 decibels).

At one of the stations built recently in the Los Angeles area all the piping was installed underground, with vaults around the orifice meters only. All valves are buried and operated with hand wheels on extensions. Pressure control is done with motor-operated plug valves with extended gearing. The gearing and pneumatic motor are above ground, mounted on an extension on the valve body. The sound created by the gas passing through the valve is somewhat greater than that created by a balanced valve regulator, but is effectively absorbed by the earth or sand back fill. Comparative sound levels were found to be:

	At M.O. Valve Pres. Regulator	*At Nearest Property Line*
Before Station Constructed	56 db	55 db
Station in Normal Operation	74 db	56 db

At the time these readings were taken there was only about 1 foot of cover over the piping. When the normal 3 feet of cover is in place, it is probable that the sound level in the immediate vicinity of the pressure control valve will be appreciably lower.

In this type of installation it is important to take into consideration the possibility of sound transmission through the extended hand wheels and operators connected to the underground piping.

Insulating Walls

The effectiveness of sound insulation applied to building walls varies greatly with the type of construction. This insulation ranges from using any available material which acts as a sound absorbent, to expensive procedures such as constructing a building with double walls on separate foundations with no structural interconnection. One building tested (Fig. 8) was constructed as follows, starting with the outside surface: 3 in. reinforced Gunite concrete, 1 in. Celotex, 3⅝ in. for 2 x 4 in. studs, 6⅞ in. dead air space and steel columns, ½ in. plain plaster board, 3⅝ in. for 2 x 4 in. studs, ½ in. Celotex, 1⅝ in. for 2 x 3 in. stripping (horizontal, 12 in. o.c.), and 1¼ in. Acousti-Celotex. The total thickness is 22 inches.

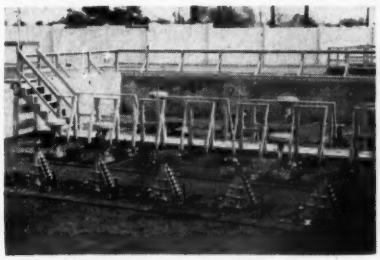


Fig. 6. Meter station with piping covered with sand and black top.

Fig. 7. Regulators and valves partially covered with sand.

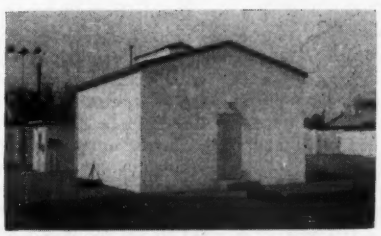


Fig. 8. Sound-insulated regulator building with double doors and no windows.

The sound-insulating efficiency of a building of this type would be improved if there were no mechanical contact between the inner and outer walls, and if they were constructed on separate foundations. Tests conducted at the building showed a sound level of 96 db inside and 60 db outside at 2 feet from the wall. This sound level decreases as the distance from the building increases; at the property line the sound from the regulator building was lower than the minimum background noise of 55 db. The loss of 36 db through the building is not a true indication of the efficiency of the wall. It is probable that part of the sound picked up outside of the building is from another source, and that the insulating efficiency of the wall is considerably better than shown by this test.

In constructing insulated buildings, or in insulating existing buildings, it is necessary to consider piping and ventilating ducts which may provide a path for noise transmission. Two solid doors of ordinary 2 in. T&G hardwood with a minimum of 8 in. dead space between are better than a special soundproof door. The two doors should accomplish approximately a 50-db reduction in sound level. Another building was constructed of a 9-in. brick wall with inner lining of ½-in. mineral wool blanket, ½-in. air space, gypsum

lath, and plaster, and equipped with double windows with air space between. The sound reduction through this building wall, which theoretically should have been 62 db, was found to be approximately 40 db. This was probably due to the fact that some of the noise outside the building did not originate inside the building.

Regulator Noise

To investigate the possibility of one type of regulator being superior to another in low noise production, a series of tests was conducted under controlled conditions of pressure drop and rate of flow. Six types of 2-in. regulators and one 2-in. plug valve were tested under identical conditions while acting as pressure-reducing valves. Volumes varied from 25 to 150 M.C.F. per hr. and pressure drops varied from 60 to 160 psi. with a constant inlet pressure of 210 psi.

The results obtained from all tests, averaged together for each regulator in order to determine their relative merits, are shown in Table II.

TABLE II.—SOUND LEVEL OF REGULATORS AND VALVES

Regulator	*Valve*	*Average Sound Level, Decibels*
Balanced valve regulators	Ratio plug	73
	Throttle plug	74
	V-port	73
	Quick-opening	77
Single-seated regulators	Angle type	94
	Straight type	80
2-in. plug valve		83

It is probable that the high sound level produced by the single-seated regulators was due largely to extreme turbulence in the gas stream downstream from the regulator. Installation of an expansion section on the outlet of the regulator would relieve this condition by lowering the velocity of the gas stream. It had been anticipated that the single-seated control valve would create a lower sound level, but such was not the case.

A test was made also on three 8-in. regulators which are connected in parallel so that any one of the three could be turned on and operated under exactly similar conditions. Two of these regulators are of the standard balanced valve type, one with a quick-opening inner valve and the other with a V-port. The third regulator is a more recent model which has no conventional diaphragm and valves but uses an expansible tube over a slotted steel sleeve which replaces both the diaphragm and the valve. It was found that the noise right at the regulator was lowest for the expansible-tube-type regulator, but that the sound two or three pipe diameters downstream was higher for the expansible-tube regulator than for the regulator with the quick-opening type valve. This might be due to the type of turbulence set up in the regulator, as in the single-seat regulator test.

The total noise levels observed for the three 8-in. regulators when operating under identical conditions are as shown in Table III.

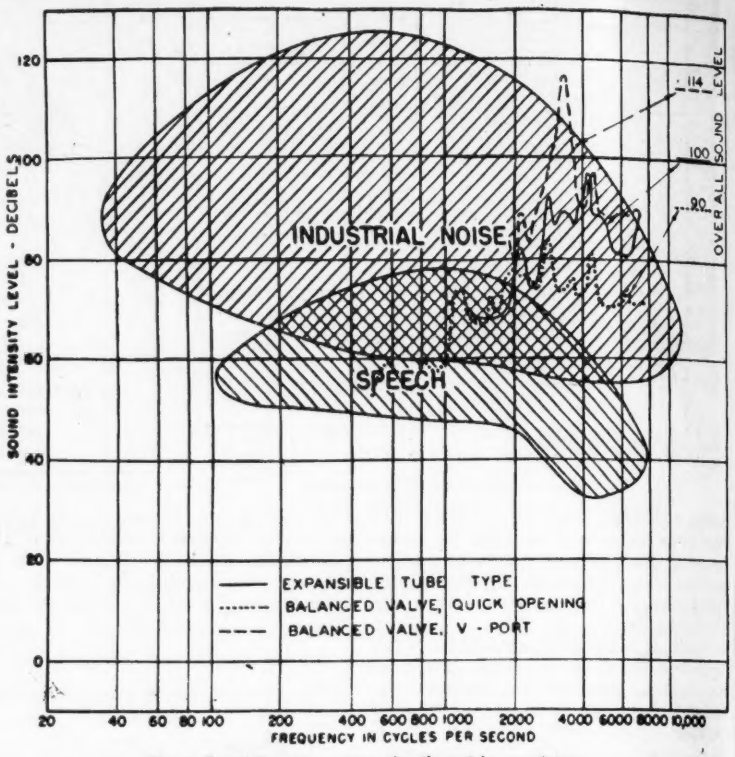


Fig. 9. Sound-frequency curves for three 8-in. regulators.

TABLE III.—SOUND LEVELS AT VARIOUS LOCATIONS

Regulator	*At Regulator*	*12 in. Downstream*	*24 in. Downstream*
Balanced valve regulator			
V-port valve	98 db	110 db	110 db
Quick-opening	87 db	89 db	89 db
Expansible-tube type	84 db	100 db	99 db

It should be pointed out that if the expansible-tube-type regulator were installed in a vault with its outlet close to the vault wall, or if the regulator were entirely buried, the sound problem would be largely overcome.

The sounds created by these three regulators were analyzed and plotted (Fig. 9) with normal speech and industrial noise areas indicated for comparison.

As pointed out previously, the frequency of sound components is as important as the total sound level. A shrill whistle or screech can be more irritating than lower-pitched sound of greater intensity. Unfortunately, pressure-reducing regulators often cause noises with a shrill whistling characteristic.

Objectionable noise conditions at pressure-reducing regulator stations can be eliminated satisfactorily by one of the methods described in this paper. The choice of methods must be governed by local conditions, cost, and the sound level permissible in the vicinity. To mask a sound entirely, it should be reduced to a level of 10 db below the background noise at the listening position, but this is not always necessary.

Consideration of the noise problem when planning new regulator stations is becoming essential. Although prompt action in eliminating objectionable noise conditions is commendable and instrumental in furthering good public relations, the use of sufficient foresight to prevent the unwanted condition from occurring is more desirable. Maintaining satisfactorily low noise levels at gas-company installations is fully as important as appearance in obtaining building permits and zone variances when needed.

Present laws are not definite in limiting noise, largely because there is no established standard as to what constitutes harmful or objectionable noise. Continuation of a policy of preventing or eliminating noises that are causes for complaint will go a long way in making the enactment of restrictive noise-abatement laws unnecessary.

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O. W. Eshbach, "Handbook of Engineering Fundamentals," p. 9-35.

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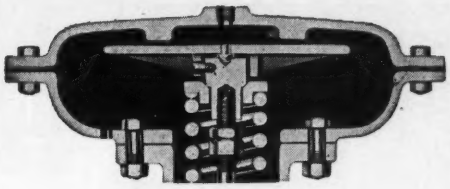

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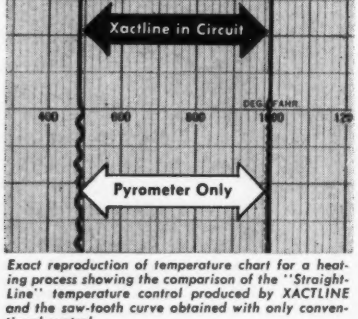

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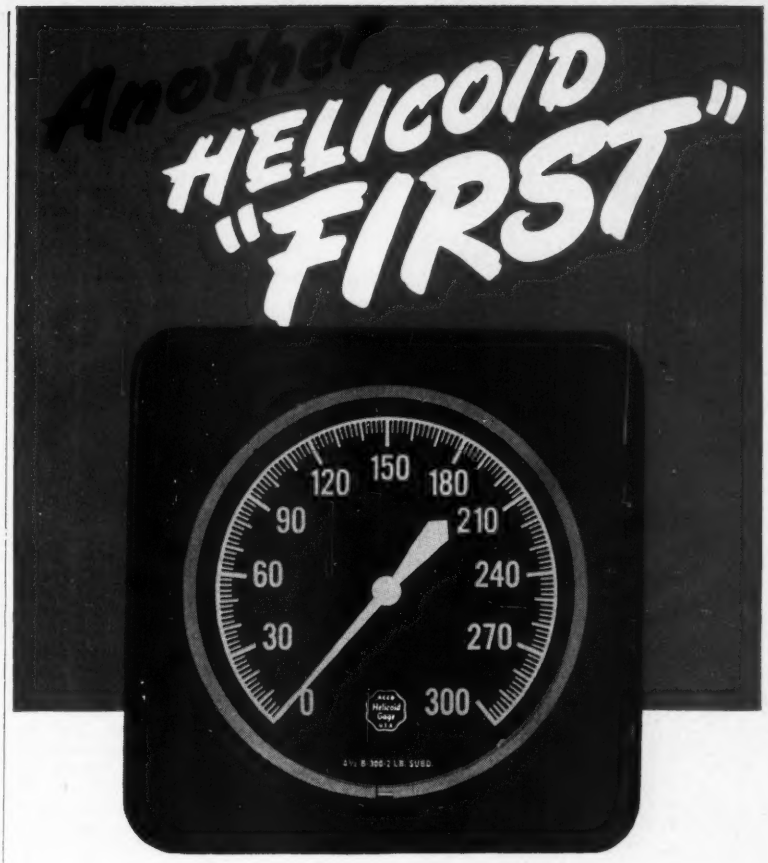

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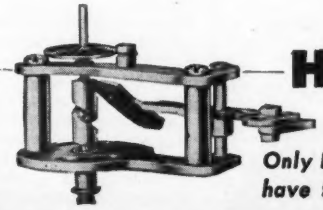

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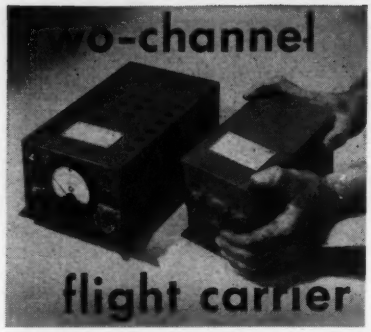

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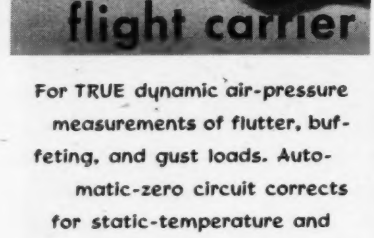

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T-920 **Oscillograph Recorder.** 1-page bulletin illustrates and describes maker's 12-channel portable oscillograph recorder.—Heiland Research Corp., 130 E. 5th Ave., Denver, Colo.

T-921 **Precision Potentiometers.** 16-page Catalog EH22(2) illustrates and describes the principles and design of "Wenner" potentiometers for precise measurement of small d-c. potentials. Includes low-range instrument for thermocouple-voltage measurement and high-range standardizing potentiometer. —Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Penna.

T-922 **Impedance Bridge.** 4-page brochure illustrates and describes maker's "Model 250-C" universal impedance bridge for measurement of resistance, capacitance, inductance, and Q. Includes principles and specifications.—Brown Electro-Measurement Corp., 4635 S. E. Hawthorne Blvd., Portland 15, Ore.

T-923 **Analog Computer.** 4-page "Laboratory Report 3" features article on new analog computer and production test of linearity of potentiometer.—Technology Instrument Corp., 531 Main St., Acton, Mass.

T-924 **Daylight Illuminometer.** 2-page Folder ND46-72(1) illustrates and describes maker's "Speedomax" illuminometer for weather observation, exposure testing, etc. Includes components and specifications.—Leeds & Northrup Co., 4907 Stenton Ave., Philadelphia 44, Penna.

T-925 **Ultrasonic Testing.** 8-page Bulletin 50-115 illustrates and describes commercial ultrasonic testing and inspection service offered by maker of "Reflectoscope" and "Reflectogage."—Sperry Products, Inc., Danbury, Conn.

T-926 **High-current Supply.** 2-page Bulletin C-1003-351 illustrates and describes maker's "Multi-Amp" portable high-current test units for relays, breakers, etc. Includes features and models.—Multi-Amp Corp., 121 Cross St., Harrison, N. J.

T-927 **Dynamometers.** 4-page Vol. 18 No. 8 issue of house organ "Electrical Measurements" discusses dynamometer-type current-product instruments and dynamometer principles.—Sensitive Research Instrument Corp., 9-11 Elm Ave., Mt. Vernon, N. Y.

T-928 **Winding-insulation Tester.** 4-page Bulletin GEC-794 illustrates and describes maker's d-c. winding-insulation tester for testing armatures, field coils, stator coils, etc. Includes components, operation, and specifications. —General Electric Co., Schenectady, N. Y.

T-929 **Magnetic Amplifiers.** 4-page brochure illustrates and describes maker's line of packaged magnetic amplifiers, single and push-pull. Includes specifications and connections.—Magnetic Amplifiers, Inc., 11-54 44th Dr., Long Island City 1, N. Y.

T-930 **Radiation Counters.** 2-page brochure illustrates and describes

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NEW LITERATURE

Electrical & Electronic Instruments Continued

maker's radiation counters and scalers. Includes high-temperature Geiger-Muller counter and other counters for solid, liquid, and gas samples.—Radiation Counter Laboratories, Inc., 1844 W. 21 St., Chicago 8, Ill.

T-931 **Film-badge Service.** Bulletin 102 describes new service which provides weekly radiation-sensitive film badges (wrist or ring mounted) and processing service.—Technical Associates, 140 W. Providencia Ave., Burbank, Calif.

T-932 **Telemetering System.** 4-page Instrumentation Data Sheet 9.1-10 illustrates and describes telemetering system which uses "General Electric Telemeter Transmitter" and "Brown Electronik" recorder. Includes principles and operation.—Minneapolis Honeywell Regulator Co., Brown Instruments Div., Station 40, Wayne and Windrim Aves., Philadelphia 44, Pa.

T-933 **Carrier Telephone System.** 4-page Form 32E-P4 illustrates and describes maker's 3- or 4-channel single-sideband suppressed-carrier telephone system for open-wire lines.—Lenkurt Electric Co., County Road, San Carlos, Calif.

T-934 **Multichannel Communication System.** 4-page Form 33B-P describes single-sideband suppressed-carrier 12-channel communication system designed for channelizing point-to-point radio communication links. Includes block diagrams and specifications.—Lenkurt Electric Co., San Carlos, Calif.

T-935 **Color Television.** 40-page Color Television Notebook Vol. 2 illustrates and describes CBS color receiver circuits. Price is $1.00.—Paul H. Wendel Publishing Co., Inc., P.O. Box 1321, Indianapolis 6, Ind.

Electrical and Electronic Components

T-936 **Electronic Components and Equipment.** 28-page Catalog 7-51 illustrates and describes maker's large line of electronic components and instruments, including capacitors, transformers, terminal boards, resistors, relays, vacuum and gas tubes, materials, pilot lights, etc.—General Electric Co., Schenectady 5, N. Y.

T-937 **Electronic Components and Instruments.** 192-page Catalog 52 illustrates and describes line of 15,000 electronic components and test instruments handled by distributor.—Radio Shack Corp., 167 Washington St., Boston 8, Mass.

T-938 **Electronic Components and Instruments.** 212-page 1952 Catalog No. 127 illustrates and describes large line of electronic components and instruments handled by distributor.—Allied Radio Corp., 833 W. Jackson Blvd., Chicago 7, Ill.

T-939 **Electronic Components.** 16-page brochure illustrates and describes manufacturer's facilities for production of electronic components such as capacitors, transformers, r-f. tuners, etc.—Edwin I. Guthman & Co., 15 S. Throop St., Chicago 7, Ill.

T-940 **Industrial Electronic Tubes.** 28-page catalog lists, illustrates, and

describes large line of industrial tubes handled by distributor. Includes Pliotrons, Kenotrons, phototubes, Thyratrons, Ignitrons, Phanotrons, rectifiers, etc.—Milo Radio and Electronics Corp., 200 Greenwich St., New York 7, N. Y.

T-941 **Miniature Power Resistors.** 2-page Bulletin R-11 illustrates and describes "Dalohm" 25-watt miniature precision resistors. Includes features and specifications.—Dale Products, Inc., Columbus, Nebr.

T-942 **Capacitors.** 16-page Vol. 16 No. 9 issue of house organ "The CD Capacitor" features description of bridge-type distortion meter and maker's capacitors.—Cornell-Dubilier Electric Corp., Hamilton Blvd., S. Plainfield, N. J.

T-943 **Potentiometer-rheostats.** 42-page catalog illustrates and describes maker's line of precision potentiometer-rheostats. Includes theoretical and actual characteristics, specifications, and index of characteristics.—The Helipot Corp., 916 Meridian Ave., S. Pasadena, Calif.

T-944 **Switches.** 4-page brochure illustrates and describes maker's standard line of switches. Includes mechanical and electrical characteristics.—The Daven Co., 191 Central Ave., Newark 4, N. J.

T-945 **Switches.** 2-page Vol. 7 No. 2 issue of house organ "Uses Unlimited" features descriptions of magnetic-blowout d-c. switches and subminiature switch assemblies.—Micro Switch, Div. of Minneapolis-Honeywell Regulator Co., Freeport, Ill.

T-946 **Switches.** 2-page Catalog S 10 illustrates and describes maker's "Type JA" rotary multi-deck selector switches. Includes specifications.—United States Instrument Corp., Summit, N. J.

T-947 **D-C. Switches.** 4-page brochure illustrates and describes new magnetic-blowout switches for high-voltage d-c. circuits. Includes specifications.—Micro Switch, Div. of Minneapolis-Honeywell Regulator Co., Freeport, Ill.

T-948 **Cables and Connectors.** 4-page Vol. 4 No. 7 issue of house organ "Engineering News" features articles on connectors, induction voltage regulators, and nonlinear potentiometers.—American Phenolic Corp., 1830 S. 54th Ave., Chicago 50, Ill.

T-949 **Terminal Blocks.** 12-page catalog illustrates and describes maker's large line of screw-type barrier terminal blocks. Includes specifications and prices.—Kulka Electric Mfg. Co., Inc., 633 S. Fulton Ave., Mt. Vernon, N. Y.

T-950 **Linear Transducers.** Engineering Data Sheets illustrate and describe maker's "Atcotran" differential transformers "Class 6204" and "Class 6205." Includes features, electrical data, and wiring diagram.—Automatic Temperature Control Co., Inc., 5200 Pulaski Ave., Philadelphia 44, Penna.

T-951 **Brazing and Soldering Pot.** 1-page bulletin illustrates and describes maker's new "Hi-Temp" dipping pot for silver-solder dipping, 50-50 lead solder, and all high-temperature dipping.—Tartak-Stolle Electronics, Inc., 3970 S. Grand Ave., Los Angeles 37, Calif.

T-952 **Test Panel.** 4-page Vol. 8 No. 4 issue of house organ "The Con-

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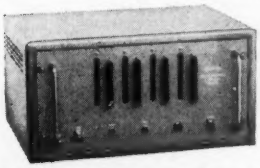

PRESET COUNTER consists of a series of scale-of-10 electronic counting units each in parallel with a 10-position push-button switch. This instrument accepts counts in the conventional manner at rates up to 10,000 cps. Any number from 0 to maximum capacity may be preset merely by depressing appropriate push-button in each column. Upon reaching the preset count, the unit supplies an output pulse to drive a register, close a gate, divert a production line or perform any other desired function. It then resets to 0 and recycles automatically. Available in any desired capacity.

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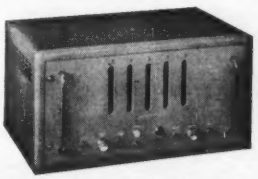

TIME INTERVAL METER, MODEL 510 provides a direct reading of elapsed time between any two events in the range of 0.000010 to 1.00000 seconds. Accuracy is ± 10 microseconds. Any occurrences that can be translated into changing voltages may be so timed. Timing may be started and stopped by independent voltages, the polarity of which may be selected by means of toggle switches. Sensitivity control permits selection of the amplitude of start or stop voltages at optimum level for elimination of interference. Dimensions 20¾" x 10½" x 15". Weight approximately 58 lbs.

SINGLE/DOUBLE PULSE GENERATOR MODEL 903 is a general purpose laboratory instrument that supplies either single or paired pulses individually variable in amplitude, width and polarity. Pulse spacing is continuously variable from 0 to 10 microseconds, pulse width from 0.10 to 1.6 microseconds and pulse amplitude from 200 volts maximum negative and 50 volts maximum positive for 1000 ohm load, and 10 volts maximum negative and 50 volts maximum positive for 50 ohm load. Single or double pulses are available through separate panel connectors. Repetition rate internally controlled 1 to 1000 cps. Push-button control single cycle. External signal control for any rate up to 1000 cps.

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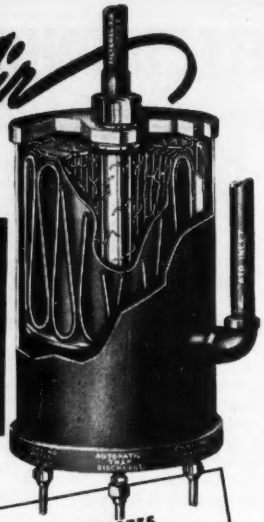

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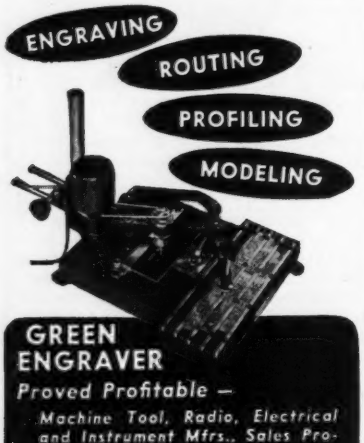

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NEW LITERATURE

necting Link" features articles on aircraft simulator and test panel for components.—Link Aviation, Inc., Binghampton, N. Y.

Valves, Piping, etc.

T-953 **Diaphragm-motor Valves.** 2-page Specification Sheet 408-2 illustrates and describes maker's "Series 700-LF" air-operated diaphragm-motor valves for wide-band proportional control of small flows. Includes specifications and applications.—Minneapolis-Honeywell Regulator Co., Industrial Div., Station 40, Wayne and Windrim Aves., Philadelphia 44, Penna.

T-954 **Diaphragm-motor Valves.** 2-page Specification Sheet 419-1 illustrates and describes maker's "Series 100" air-operated diaphragm motor valves for narrow-band proportional control. Includes specifications and applications.—Minneapolis-Honeywell Regulator Co., Industrial Div., Station 40, Wayne and Windrim Aves., Philadelphia 44, Penna.

T-955 **Valve Actuators.** 4-page Bulletin 512 illustrates and describes maker's power-cylinder-type valve actuators for all type valves. Includes principles, operation, and capacities.—Ledeen Mfg. Co., 1600 So. San Pedro St., Los Angeles 15, Calif.

T-956 **Pneumatic Throttling Valve Positioner.** 8-page Bulletin C-1 illustrates and describes new "Rotomotor" pneumatic heavy-duty gear-driven valve positioner for throttling service. Includes features and operation.—Conoflow Corp., 2100 Arch St., Philadelphia 3, Penna.

T-957 **Miniature Valves and Controllers.** 4-page bulletin illustrates and describes maker's miniature diaphragm-motor valves, positioners, level controllers, etc., for pilot plants and research laboratories.—Research Control Instrument Co., 8211 E. 7th St., Tulsa, Okla.

T-958 **Magnetic Gas Valve.** 4-page folder Form 601.201 illustrates and describes maker's "K-3H Magnetic Gas Valve." Includes features.—General Controls, Chicago 5, Ill.

T-959 **Gate Valve.** 4-page Bulletin 535 illustrates and describes maker's new 75-psi. gate valve with aluminum body for fuel and oil systems.—The Parker Appliance Co., 17325 Euclid Ave., Cleveland 12, Ohio.

T-960 **Tank Cleanout Valve.** 6-page Bulletin 4000-1515 illustrates and describes maker's safety cleanout valve for tanks with volatile liquids.—Liquidepth Indicators, Inc., One Star Sq., Long Island City 1, N. Y.

T-961 **Safety Valves.** 16-page Bulletin 851 "Sizing Safety Valves for Pressure Reducing Regulators" has charts for selecting valves. Includes description of maker's line of safety relief valves.—Marine and Industrial Products Co., 3731-35 Filbert St., Philadelphia 4, Penna.

T-962 **Hydraulic Valves.** 28-page Catalog 203 illustrates and describes maker's line of 138 models of hydraulic valves, including 4-way valves, oil pilot valves, hydraulic sequence valves, etc.—Rivett Lathe & Grinder, Inc., Brighton 35, Boston, Mass.

T-963 **High-pressure Reducer.** 2-page Supplement to Catalog E-1457

illustrates and describes new "Ermeto" high-pressure reducer which can handle pipe reduction from 2 to 1/8 in.—The Weatherhead Co., Industrial Sales Div., Cleveland 8, Ohio.

Inspection and Testing

T-964 **Universal Tester.** 4-page Bulletin M illustrates and describes maker's multi-low-range universal tester for elongation and compression tests, etc. Includes features and operation. —W. C. Dillon & Co., Inc., 1421 S. Circle Ave., Forest Park, Ill.

T-965 **Tensile-strength Tester.** 1-page Circular 129 illustrates and describes "Type 274" horizontal-model motor-driven pendulum-principle tensile-strength tester.—Amthor Testing Instrument Co., Inc., 45 Van Sinderen Ave., Brooklyn 7, N. Y.

T-966 **Surface Analysis.** 8-page folder "Surface Evaluation by Faxfilm" illustrates and describes "Faxfilm" process which employs a plastic to show surface conditions of material of any shape.—The Brush Development Co., Instrument Div. 33, 3405 Perkins Ave., Cleveland 14, Ohio.

T-967 **Depth Gage.** 1-page bulletin illustrates and describes maker's "Universal Depth Gage Model DG-56-R-1," including features.—Saart, Kraemer & Hanscom, Inc., 1 Washington Ave., Providence, R. I.

Miscellaneous

T-968 **Industrial Lubricant.** 8-page Bulletin 93 presents case histories describing use of "Molykote" lubricant for dies, threads, instruments, etc.—The Alpha Corp., 179 Hamilton Ave., Greenwich, Conn.

T-969 **Fexible Controls.** 12-page booklet illustrates and describes maker's "Tru-Lay Flexible Push-Pull Controls," which use flexible shaft for transferring push-pull motions. Includes features and models.—American Chain & Cable Co., Inc., Automotive & Aircraft Div., 601 Stephenson Bldg., Detroit 2, Mich.

T-970 **Remote Controls.** 4-page Bulletin 20-106 illustrates and describes maker's hydraulic self-contained remote controls which replace cables, pulleys, etc.—Sperry Products, Inc., Danbury, Conn.

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T-971 **Electroplating Rectifier.** 1-page bulletin illustrates and describes "Mellaphone Style RA" convection-cooled electroplating rectifier. Includes features and types.—Electronic Rectifier Co., Inc., Rochester 2, N. Y.

T-972 **Engraver.** 2-page bulletin illustrates and describes portable "Mod-

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NEW LITERATURE

Miscellaneous Continued

el I-S Engravograph" for engraving 25-in. panels. Includes specifications.—New Hermes, Inc., 13-19 University Pl., New York 3, N. Y.

T-973 **Metal Housings.** 28-page Catalog No. 48 illustrates and describes maker's large line of cabinets, chassis, panels, and racks for electronic equipment.—Par-Metal Products Corp., 32-62 49th St., Long Island City 3, N. Y.

Calendar of Events

Nov. 26-Dec. 6
23rd Exposition of Chemical Industries.
Grand Central Palace, New York, N. Y.
C. F. Foth, Mgr., International Exposition Co., Grand Central Palace, New York 17.

Nov. 28-30, 1951
Scientific Apparatus Maker's Association.
Midyear Meeting, Laboratory Apparatus, Optical, Nautical, Aeronautical, Military Instruments Sections.
Hotel New Yorker, New York, N. Y.

Nov. 28-30, 1951
Society for Experimental Stress Analysis.
Annual Meeting & Exhibits.
Bellevue Stratford Hotel, Philadelphia.
Symposium subject: Education and Training for Experimental Analysis.

Dec. 4, 1951
Society for Applied Spectroscopy.
Regular meeting, 8 P.M., Socony Vacuum Training Center, 63 Park Row, New York City.
For information write C. A. Jedlicka, Sec., c/o Lucius Pitkin, Inc., 47 Fulton St., New York City.

Dec. 6-7, 1951
AIEE Committee on Feedback Control Systems.
Conference on Feedback Control.
Scientists and engineers from various universities and industrial organizations will be on the program.
Chalfant-Haddon Hall Hotel, Atlantic City, N. J.

Dec. 10-12
Joint AIEE-IRE Computer Conference.
Conference agenda is to emphasize useful results obtainable from present large-scale digital computers.
Benjamin Franklin Hotel, Philadelphia, Dec. 10 and 12. Edison Bldg., Phila., Dec. 11.
For information write Raymond C. Mayer Associates, 9 Rockefeller Plaza, New York City.

Dec. 27-30, 1951
American Microscopical Society Meeting.
Benjamin Franklin Hotel, Philadelphia.
For information write to Frank E. Eggleton, Sec., c/o Dep't of Zoology, University of Michigan, Ann Arbor, Mich.

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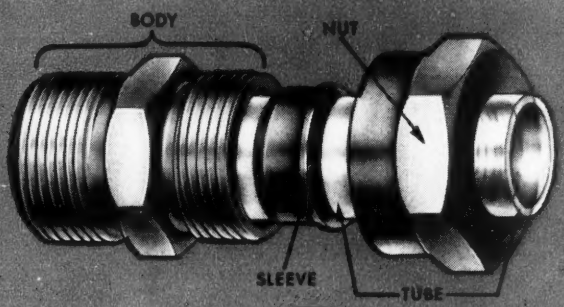
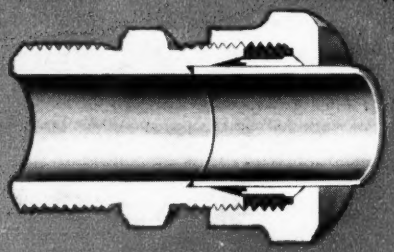
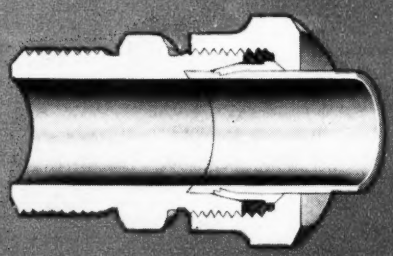


1. Sleeve is heart of Ermeto Fitting. Sleeve and nut slip onto tube; end of tube inserts into body of fitting.



2. Tighten nut; pilot of sleeve contracts engaging outer surface of tube.



3. Fully tightened. Tube end butts tight against body shoulder. Nut presses sleeve bevel causing entire sleeve to clamp tube. Forces acting on sleeve cause it to bow, give it a spring action which holds tension between body and nut—prevents loosening.

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